EXHIBIT 7

SU-5072

CLIENT or TITLE
DIVISION OF
CONTINUATION IN PART OF

JG-SU-5072

INVENTOR Cindy KOHANEK and Gary BABB

SERIAL NO. 09/904,425 FILED July 12, 2001

TITLE PRIMARY FLAT LINEARITY GAUGE

ASSIGNEE Mitsubishi ~~Silicon~~ Materials Silicon Corp.

ASSIGNMENT RECORDED March 11, 2002 REEL 012730 FRAME 0063

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Executed Decl. mailed 2-13-2002 filed 2-13-2002	~~Status~~ 8-13-2002
OA 3516.02 RCVD	Oct. 3, 2002 Reply Due / Jan. 3, 2003 Deadline
Petition to Revive mailed 2-6-2003 filed 2-6-2003	Awaiting Answer to Petition 6-6-2003
Abandonment Recd 3-26-2003	

CANADIAN

INVENTOR

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Client: SUDA PATENT OFFICE

Matter: LINEARITY MEASURING APPARATUS FOR WAFER ORIENTATION FLAT, SERIAL NO. 09/904,425 (SU-5072)

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Publication Notice RCVD 10-11-2002
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Publication Date: 12-19-2002

OTHER FOREIGN

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PATENT NO. ______ DATE ______

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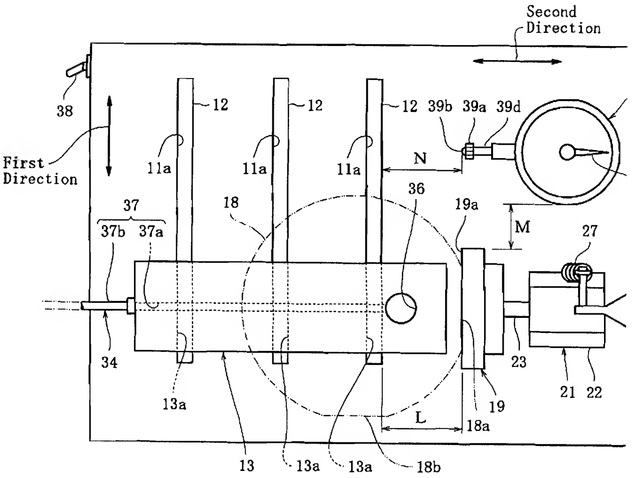
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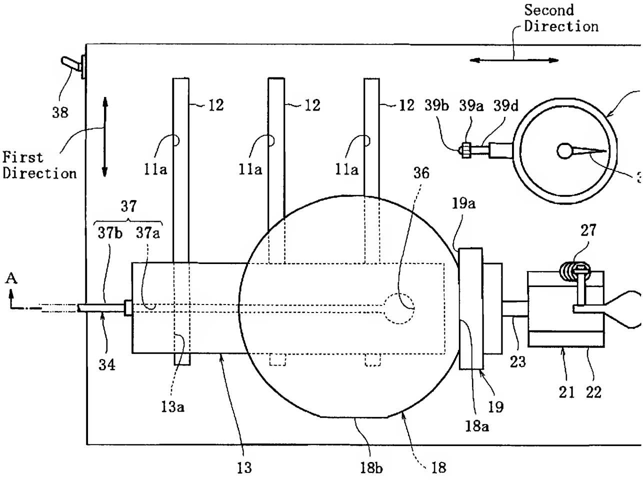
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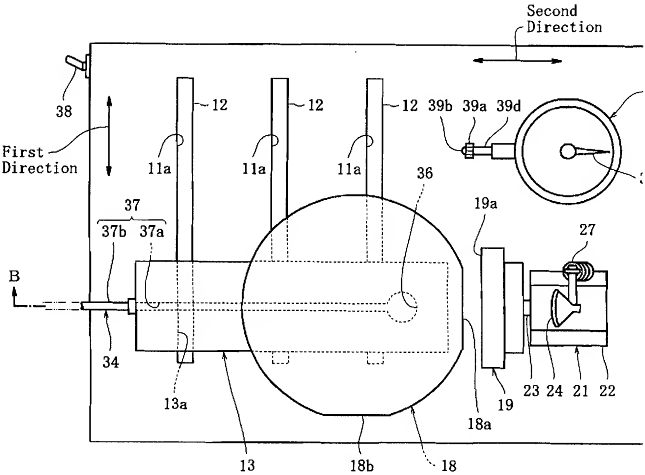
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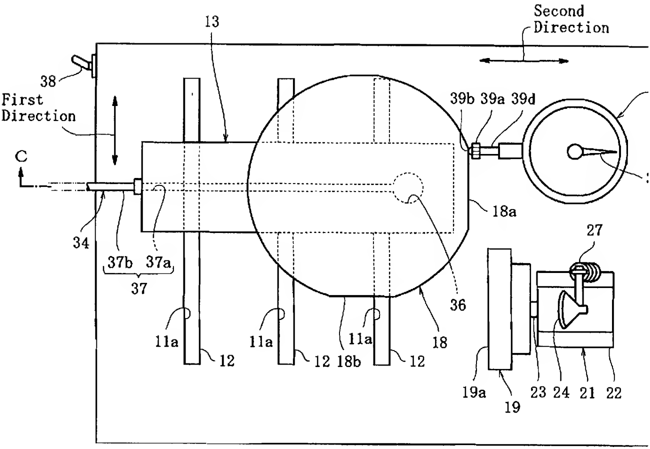
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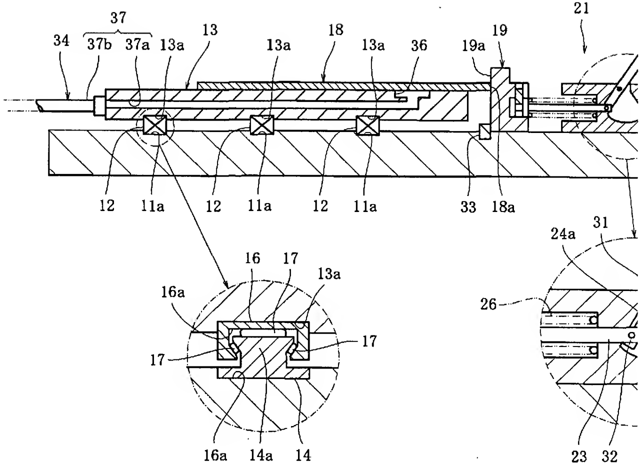
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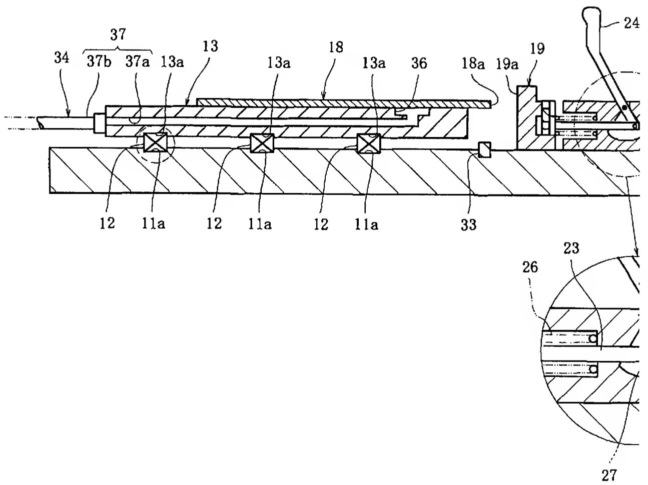
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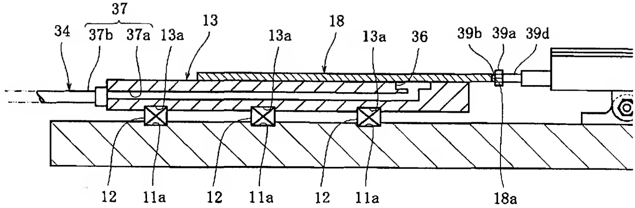
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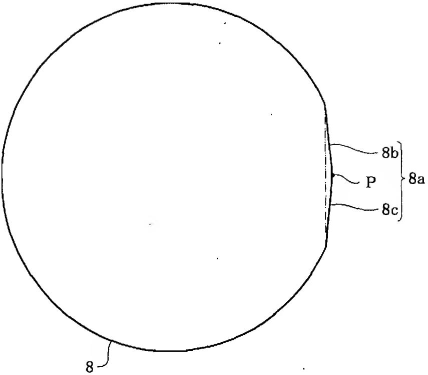
Fig. 8

(a)



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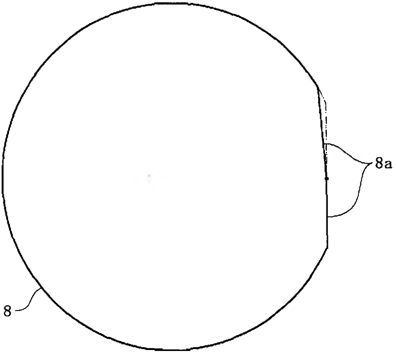

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United States Patent [19]
Danielli et al.
[11] Patent Number: 4,680,865
[45] Date of Patent: Jul. 21, 1987

[54] APPARATUS FOR CHECKING LINEAR DIMENSIONS

[75] Inventors: Franco Danielli, Zola Predosa; Sergio Solaroli, Bologna, both of Italy
[73] Assignee: Finike Italiana Marposs S.p.A., S. Marino di Bentivoglio, Italy

[21] Appl. No.: 836,416
[22] Filed: Mar. 5, 1986
[30] Foreign Application Priority Data
Apr. 1, 1985 [IT] Italy 3386 A/85
[51] Int. Cl.⁴ G01B 7/28
[52] U.S. Cl. .... 33/143 L; 33/504; 33/1 M; 33/549
[58] Field of Search .... 33/504, 143 L, 147 N, 33/542, 549, 1 M, 147 M, 179.50

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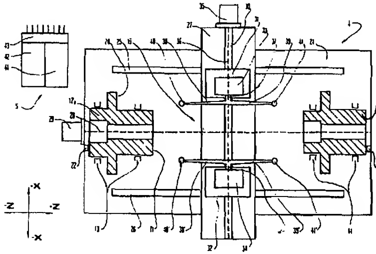
Primary Examiner—Willis Little
Attorney, Agent, or Firm—Stevens, Davis, Miller & Mosher

[57] ABSTRACT

An apparatus for checking linear dimensions of mechanical parts comprises a bed, a longitudinal slide and two transverse slides arranged on the longitudinal slide and carrying relevant sensing elements adapted to touch the part to be checked. In order to obtain flexibility and quickness of operation, first and second reference rests for relevant parts are positioned on the bed and the transverse slides carry sensing elements having an arrangement substantially symmetrical with respect to a transverse symmetry plane. The apparatus is particularly suitable for checking parts after a first and, respectively, a second machining operation.

16 Claims, 5 Drawing Figures



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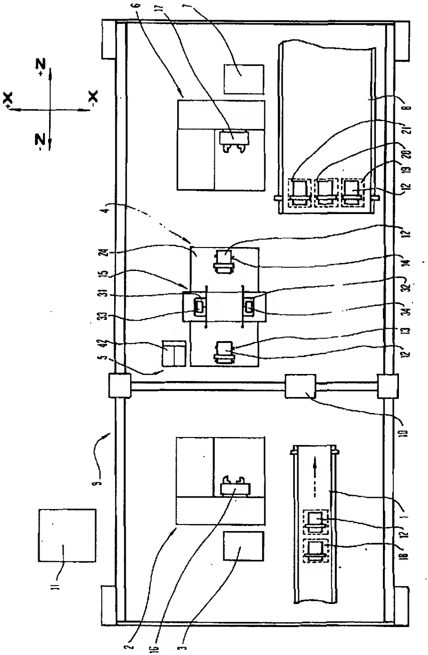

FIG. 1

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U.S. Patent Jul. 21, 1987 Sheet 2 of 4 4,680,865

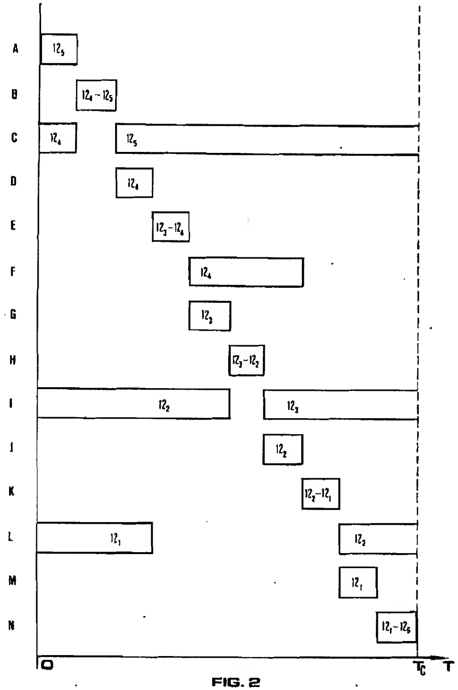

FIG. 2

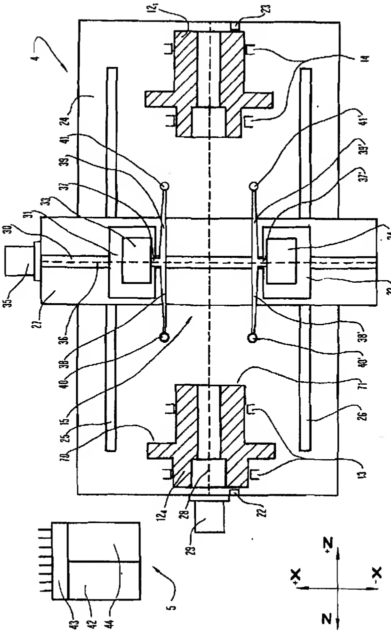

FIG. 3

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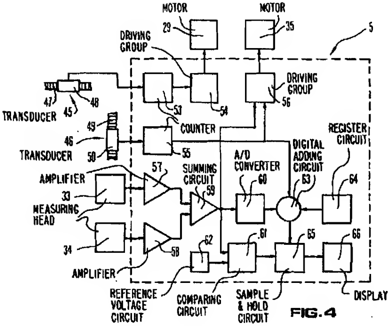
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SUMMING CIRCUIT
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MEASURING HEAD
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AMPLIFIER
REFERENCE VOLTAGE CIRCUIT
COMPARING CIRCUIT
SAMPLE & HOLD CIRCUIT
DISPLAY

FIG. 4

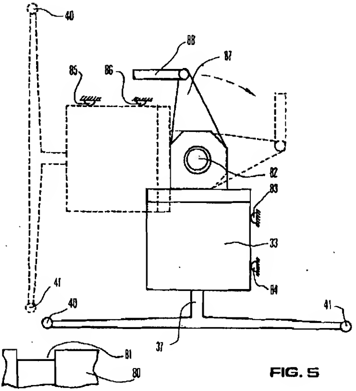
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FIG. 5

APPARATUS FOR CHECKING LINEAR DIMENSIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus for checking dimensions of mechanical parts, comprising a support base, first and second reference rests, for mechanically positioning first and second mechanical parts, measuring units coupled to the support base for checking both the first and the second parts and driving and control units adapted to cause a mutual displacement between the measuring units and the reference rests for achieving a mutual positioning between the measuring units and the first and second parts.

2. Description of the Prior Art

As it is known, the parts that are employed in the mechanical industry, for example in the motor car industry, normally are subjected to subsequent machining operations in the same or, more frequently, in different machine tools.

In particular, with reference to turning machines, although the modern lathes for mass production are very broadly automated and at the same time flexible, due to the use of computer numerical controls, automatic systems for part handling and tool replacement, rotary tools and also, recently, automatic systems for jaw changing, very frequently machining operations are performed, in which a first part is loaded into the chuck of a first lathe—that grips it at an end—is machined by this lathe, then is unloaded and loaded into the chuck or another lathe that grips it at the other end, in order to machine the part in correspondence with the portion previously gripped by the chuck of the first lathe. Of course, while the second lathe machines the first part, the first lathe machines a subsequent part, and so on.

It is also known to use—in view of the trend to reduce the tolerances of the machined parts, to automate the operations consequently diminishing the number of operators or eliminating them, and to shorten the cycle times—measuring apparatuses for automatically checking the dimensions of the machined parts. In particular, known apparatuses are adapted to "post-process" check parts machined in lathes as far as internal or external diameters, thicknesses, longitudinal distances, cylindricity, etc. are concerned.

Usually, these apparatuses are served by the same automatic workhandling systems that serve the lathe (pallet conveyors, robots, gantry loaders, etc).

Since the modern lathes are adapted to machine—depending upon relevant programs loaded into computer numerical controls—parts of different types with very short cycle times and in view of a rising trend towards batch machining, important features of the post-process measuring apparatuses are the flexibility, i.e. the capability of checking different parts without the need of complex operations for retooling of the apparatus, and the quickness, in addition—of course—to high accuracies and repeatabilities of the measurements.

The obtainment of a suitable compromise among these contrasting requirements is not easy and generally involves high costs for the measuring apparatuses. In order to reduce the costs of measuring apparatuses adapted to check parts of different types, it is known to use a common handling system capable of performing a mutual displacement between measuring means and a plurality of parts, positioned by mechanical reference means.

In particular, German Pat. No. 1101777 describes an apparatus in accordance with the preamble of the first claim, comprising a rotary disc—with mechanical reference means for positioning a plurality of parts, of different types, in correspondence with the periphery of the disc—and a plurality of stationary measuring stations. The parts are displaced to relevant measuring stations through step by step rotations of the disc.

This known apparatus is not flexible as far as the measuring means are concerned, because every station is adapted to check a determined type of part. Therefore, this apparatus does not meet the requirements necessary for the abovedescribed applications.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a measuring apparatus that, besides guaranteeing high accuracy and repeatability, is very flexible and fast and has limited cost.

According to the present invention, in the apparatus set forth at the beginning of the disclosure, the first and second reference rests are arranged in positions substantially fixed with respect to the support base and the measuring unit comprise a first slide movable on the support base, at least a second slide movable on the first slide, first sensing unit arranged on the second slide and transducer unit adapted to detect the positions of the first and second slides, the first sensing unit being adapted to be arranged in a position substantially symmetrical with respect to the first and second reference rests.

The invention solves the problem of checking, by using the same measuring unit, parts of different types arranged in different mechanically referenced positions.

Through an apparatus of this type the following results and advantages are achieved: the apparatus is particularly suitable for checking parts undergoing a first and a second operation in two different lathes or on the same lathe (having a single or a double spindle). In the case of machining operations on a pair of lathes, the apparatus can be located according to an arrangement substantially symmetrical with respect to the two lathes, this rendering easier the workhandling operations. The measuring unit may have an arrangement and a location symmetrical with respect to first and second reference rests for relevant parts and this is advantageous for quickly bringing the measuring unit into cooperation with the parts located on the first and second reference rests. These symmetrical arrangement and location permit the use of simple kinematic elements and contribute to the accuracy and repeatability of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be now more detailedly described with reference to a preferred embodiment illustrated in the annexed drawings, to be intended however as an example only.

FIG. 1 is a simplified schematic plan view showing a machining and measuring cell including two latches and one measuring apparatus;

FIG. 2 is an explanatory diagram of the various phases of one operating cycle of the cell of FIG. 1;

FIG. 3 is a simplified schematic plan view of the measuring apparatus;

FIG. 4 is a functional block diagram of some circuits of the apparatus of FIG. 3; and

FIG. 5 schematically shows, with enlarged scale, a variant of the apparatus of the preceding figures.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The machining and measuring cell schematized in FIG. 1 comprises an input conveyor 1, a first lathe 2 with relevant computer numerical control (CNC) contained within a cabinet 3 also housing a programmable controller, a measuring apparatus 4 controlled by a CNC 42 contained within a cabinet 5, a second lathe 6 with relevant CNC and electric cabinet 7, an output conveyor 8, a gantry loader 9, with a carriage 10 having double gripper, and a central computer 11 that controls the driving members of loader 9 and conveyors 1 and 8, coordinating them with the computer numerical controls housed within cabinets 3, 5, 7.

The cell of FIG. 1 is of a known type, apart from the measuring apparatus 4.

The parts 12 are subsequently advanced by input conveyor 1, with step by step motion, to a pick-up position.

The carriage 10 of gantry loader 9 moves suitably and picks up from conveyor 1, through one of the grippers, not shown, a first part 12, that is loaded onto the spindle 16 of lathe 2, where it is chucked at one end. After machining on lathe 2, carriage 10 picks up the first part 12, loads onto spindle 16, through the other gripper, a second part 12 previously picked up from conveyor 1 and carries the first part 12 onto first reference rests 13 of apparatus 4. CNC 42 controls the displacement of measuring units 15 towards the first part 12, that is checked. If the results of the checkings indicate that this part 12 is good, as far as the previously performed operation is concerned, carriage 10 picks up again the same part 12 and carries it to the second lathe 6. The part 12 is chucked onto spindle 17 of lathe 6 in correspondence with the previously machined end and is machined at the other end.

Then carriage 10 picks up again the first part 12 and carries it onto second reference rests 14 of apparatus 4. CNC 42 controls the displacement of the measuring units 15 in order to perform another checking on the first part 12.

On the basis of the result of the second checking, carriage 10 picks up the part 12 and arranges it in a relevant unloading position onto conveyor 8, depending on whether the part 12 is good, unrecoverable scrap or scrap recoverable through further machining operations.

The diagram of FIG. 2 shows a possible time chart of the operating phases of the cell of FIG. 1 during a cycle of duration T_C.

The abscissas relate to the time T and the ordinates indicate the actual phases for six subsequent parts 12, denoted by 12_1–12_6.

Letters A to N indicate the following phases:

A: transport of a part 12 from conveyor 1 to lathe 2. In the case of FIG. 2 the active phase refers to the transport of part 12_5;

B: exchange of two parts 12 on lathe 2. In the case of FIG. 2 the active phase refers to the exchange between parts 12_4 and 12_5;

C: machining on lathe 2;

D: transport from lathe 2 towards reference rests 13;

E: exchange of two parts 12 onto reference rests 13;

F: measurement of a part 12 on reference rests 13;

G: transport of a part 12 from reference rests 13 to lathe 6;

H: exchange of two parts 12 on lathe 6;

I: machining on lathe 6;

J: transport from lathe 6 to reference rests 14;

K: exchange of two parts 12 on reference rests 14;

L: measurement of a part 12 on reference rests 14;

M: transport of a part 12 from reference rests 14 to conveyor 8;

N: unloading of a part 12 onto conveyor 8 and picking up of a new part 12 from conveyor 1.

The operating cycle of the cell can occur differently from what is shown in FIG. 2. For example, in case the measuring apparatus 4 detects that a part 12 must be considered recoverable or unrecoverable scrap, just after machining on the first lathe 2, this part can be directly unloaded onto output conveyor 8, in a suitable position.

As shown by FIG. 1, the structure of lathes 2 and 6—in particular with respect to the arrangement of the spindles 16, 17—and that of reference rests 13, 14 are such that the parts 12 maintain the same orientation both on lathes 2, 6 and on measuring apparatus 4.

The same applies to conveyor 1, where the parts 12 are located on seats 18, and to conveyor 8, that has seats 19, 20, 21, respectively for good, recoverable and unrecoverable scrap parts 12. This permits simplifying the members and operations for handling parts 12.

The measuring apparatus 4 is now further described with reference to FIG. 3.

The reference rests 13, 14, each defines a V-shaped reference structure for positioning the parts 12 (featuring basically a rotational symmetry) along a transverse direction $\pm X$. Moreover, abutment elements 22, 23 assure axial positioning of the parts 12 (12_4 and 12_1 in FIG. 3), i.e. along a longitudinal direction $\pm Z$.

The reference rests 13, 14, abutments 22, 23 are supported by support base 24 having longitudinal guides 25, 26 enabling sliding of the measuring units 15.

The measuring units 15 of apparatus 4 comprise a first, longitudinal slide 27, coupled to a motor 29 through suitable kinematic members 28, for example with lead screw and split nuts.

Longitudinal slide 27 has a transverse guide 30 along which are movable two transverse slides 31, 32 carrying relevant sensing units constituted by comparative measuring heads 33, 34. The transverse slides 31, 32 are contemporaneously driven by a motor 35, coupled through suitable kinematic members to the same slides. These kinematic members 36—that can comprise, for example, a stem with two threads, one of which is a right-hand and the other a left-hand thread—permit transforming the clockwise and counterclockwise rotary motions of motor 35 into, respectively, mutual approaching and moving away displacements of transverse slides 31, 32.

Slides 31, 32 and measuring heads 33, 34 are always arranged symmetrically with respect to the geometric longitudinal axis of apparatus 4 and/or to the longitudinal symmetry plane defined by the first 13 and second 14 reference rests and containing this geometric axis.

In rest conditions, longitudinal slide 27 and transverse slides 31, 32 are arranged in correspondence with the transverse geometric axis of apparatus 4 and measuring heads 33, 34 have an arrangement substantially symmetrical with respect to the first 13 and second 14 reference rests.

Measuring heads 33, 34 are identical and substantially of known type, therefore are not described in detail. Head 33, for example, comprises a sensing element or movable arm 37 supported by two movable arm-sets, for example of the type featuring resilient parallelograms, so as to be movable substantially along two axes ±Z and ±X, where Z and X are the directions of the longitudinal and transversal geometrical axes of apparatus 4. Elements of head 34 corresponding to those of head 33 are indicated by the same reference numerals, with additional apexes. Of course, movable arm 37' of head 34 is displaceable along ±Z and ±X.

Movable arm 37 has feeling units including two opposite extensions 38, 39 carrying relevant feelers 40, 41 that, in rest position, are symmetrically arranged with respect to the geometrical axis of slide 27, i.e. to the transverse geometrical axis of apparatus 4. Feeler 40 is adapted to touch part 12_4 arranged on reference rests 13 and feeler 41 is adapted to touch part 12_1 arranged on reference rests 14.

Heads 33, 34 also comprise position transducers, for example of the differential transformer type, adapted to measure the displacements of movable arms 37, 37' from a rest position.

Housed within cabinet 5, in addition to CNC 42, are input/output circuits 43 and a programmable controller 44.

Among other things, the input/output circuits 43 are connected, to motors 29 and 35, measuring heads 33, 34 and transducer units constituted by two incremental linear transducers 45, 46 (FIG. 4).

Linear transducer 45, of the optical scale type, is preferably arranged in such a way as to define a geometrical axis coinciding with the longitudinal axis of apparatus 4 and comprises a graduated scale 47 fixed to base 24 and a slide 48 fixed to slide 27.

Linear transducer 46 comprises a graduated scale 49 fixed to slide 31 and a slide 50 fixed to slide 32.

The simplified functional diagram of FIG. 4 schematizes the transducer and measuring units, the driving and control unit and processing unit of apparatus 4. In particular, the diagram of FIG. 4 illustrates the functions of some of the circuits contained within cabinet 5 with reference to the checking of an external diameter.

Linear transducer 45 is connected to a counter 53 that in its turn is connected to a group 54 driving motor 29. Linear transducer 46 is connected, through a counter 55, to a group 56 driving motor 35.

Groups 54 and 56 are controlled depending on the program loaded into numeric control 42.

The output signals of measuring heads 33 and 34 reach, through two amplifiers 57, 58, an analog summing circuit 59. The output of the analog summing circuit 59 is connected to groups 56, to the input of an analog/digital converter 60 and to a comparing or enabling circuit 61 having another input connected to a circuit 62 providing a reference voltage.

A digital adding circuit 63 has three inputs, respectively connected to the outputs of counter 55, converter 60 and of a register circuit 64, and an output connected to a sample and hold circuit 65.

Circuit 65, that has a second input connected to circuit 61, has an output connected to a display unit 66.

The operation of measuring apparatus 4 will now be described, when performing the measurement of an external diameter of part 12_4 depending on the relevant program loaded into numeric control 42.

In rest position, slide 27 is in the position of FIG. 3, while slides 31 and 32 are in the position of maximum distance (i.e. feelers 40 and 40' are located at the maximum mutual distance they may reach).

Under the control of CNC 42, motor 29 causes slide 27 to translate along direction −Z until feelers 40, 40' are arranged in correspondence with the cross-sections of part 12_4 the external diameter of which must be checked.

The exact positioning of slide 27 is obtained through linear transducer 45.

Then motor 35 is actuated, depending on the program loaded into numeric control 42, and causes slides 31 and 32 to mutually approach, by displacing them along directions −X and +X, respectively. The mutual position of slides 31 and 32, that are always arranged symmetrically with respect to the longitudinal axis of the apparatus 4 and to the geometrical axis of part 12_4 (i.e., to the symmetry plane defined by reference means 13), is detected by linear transducer 46. Driving group 56, depending on the value of the output signal of summing circuit 59, controls a speed decreasing and then the stop of motor 35.

During an initial zero-setting operation of apparatus 4 on a master part, in register circuit 64 is memorized a correction value that depends on several parameters, such as the dimensions (the diameter) of feelers 40, 40', their distance in rest conditions and the values of the signals of transducer 46 and measuring heads 33, 34, in rest condition, too.

Therefore, it is evident that when feelers 40, 40' touch part 12_4 and measuring heads 33, 34 operate in their linear working range, the output signal of digital adding circuit 63 is indicative of the external diameter of part 12_4.

This measurement signal is detected and memorized by circuit 65, that is enabled by comparator 61.

Finally, the output signal of circuit 65 is displayed by unit 66 and possible recorded by a printer contained in cabinet 5.

If the detected diameter value corresponds to a scrap part 12_4, CNC 42 transmits to computer 11 a signal for controlling unloading of part 12_4 onto conveyor 8.

The measurement of external diameters (and similarly that of internal diameters) can occur statically or dynamically (i.e. with stationary or moving slides 31, 32), by combining the signal of transducer 46 with those of heads 33, 34.

Since the measurement of every diameter takes place by using the signals of two measuring heads 33, 34 when both the relevant feelers 40, 40' are into contact with part 12_4, high speed and accuracy are achieved.

Checking of axial dimensions, too, e.g. of the distance between surfaces 70 and 71 of part 12_4 is made by using the two heads 33 and 34, the signals of which are combined with the signal of transducer 45.

In this way, it is possible to refer the measured axial distance to the longitudinal axis of apparatus 4, so guaranteeing high accuracy and repeatability.

The circuits for detecting and processing the measurements are not further described since they are not one specific object of the invention and because similar circuits are described in U.S. Pat. No. 4,562,648—Danielli.

According to the present invention, heads 33, 34 and transducers 45, 46 are also used, as previously mentioned, for checking the dimensions of parts, e.g. part 12_1 of FIG. 3, arranged on reference rests 14 and abut-

ment 23. This involves evident technical and economical advantages.

For parts having particular shapes, the shape of extensions 38, 39 can be different. Moreover, always for parts having particular shape, it can be of advantage to use the variant referred to in FIG. 5.

With reference to FIG. 5, if it is desired to check a part 80 having rotational symmetry and featuring a peripheral groove 81, head 33 (and similarly head 34), rather than being rigidly fixed to slide 31, is mounted through coupling means adapted to define at least two positions on head 33. In particular, head 33 is rotatable about an axis or pin 82 fixed to slide 31 and may be arranged in two positions—shown by continuous and dashed lines—defined by abutments 83, 84 and 85, 86 fixed to slide 31. The displacement can be manually or automatically obtained acting on a lever 87 so as to cause a 90° rotation of head 33.

A control element 88 can control the displacement, for example through a double-acting cylinder, and apply a resilient thrust, for example of pneumatic type, for accurately defining the positions of head 33 against abutments 83, 84 or 85, 86.

Reference means 13, 14, 22, 23 can also be made in such a way as to be adjustable or readily replaceable, for permitting the quick retooling of the apparatus 4 to check parts of possibly very different shapes and dimensions.

What is claimed is:

1. An apparatus for checking dimensions of mechanical parts, comprising: support means; first and second reference means arranged in positions substantially fixed with respect to the support means, for mechanically positioning first and second mechanical parts; measuring means coupled to the support means for checking both the first and the second parts, the measuring means including a first slide movable on the support means, a second slide and a third slide, both movable on the first slide, first and second sensing means arranged on the second and third slides respectively and transducer means adapted to detect the positions of the first, second and third slides, the first and second sensing means being adapted to be arranged in positions substantially mutually symmetrical with respect to the first and second reference means; and driving and control means adapted to cause displacements of the measuring means for achieving positioning of the measuring means with respect to the first and second parts.

2. The apparatus according to claim 1, wherein said first and second reference means are adapted to define a longitudinal symmetry plane, said first slide is movable along a longitudinal direction and said second and third slides are movable along a transverse direction.

3. The apparatus according to claim 2, wherein said second and third slides are arranged in symmetrical positions with respect to said longitudinal symmetry plane.

4. The apparatus according to claim 3, wherein said transducer means comprise a first transducer adapted to detect the position of the first slide with respect to the support means and a second transducer adapted to detect the mutual position of the second and third slides.

5. The apparatus according to claim 4, wherein said first and second sensing means comprise two heads, each head having relevant feeling means adapted to touch the first and second parts, the feeling means having an arrangement substantially symmetrical with respect to said longitudinal symmetry plane.

6. The apparatus according to claim 5, wherein the feeling means of each head comprise a movable arm bearing two feelers, one of the feelers being adapted to touch the first parts and the other feeler being adapted to touch the second parts.

7. The apparatus according to claim 1, wherein said driving and control means comprise a first motor for controlling displacements of the first slide and at least a second motor for controlling mutual displacements of the second and third slides.

8. The apparatus according to claim 6, wherein said heads are measuring heads and said movable arm is movable along at least two axes.

9. The apparatus according to claim 2, for checking first parts after a first machining operation and for checking second parts obtained from the first parts through a second machining operation, wherein said first and second reference means are adapted to support the relevant parts with the same orientation with respect to said longitudinal direction.

10. The apparatus according to claim 9, wherein said first and second reference means comprise rests for positioning the parts along said transverse direction and abutments for positioning the parts along said longitudinal direction.

11. The apparatus according to claim 1, wherein said first sensing means are arranged on the second slide through coupling means adapted to define at least two positions of the first sensing means with respect to the second slide.

12. The apparatus according to claim 1, wherein said first and second sensing means are arranged on the second and third slides, so as to be rotatable about relevant axes, the second and third slides defining abutments adapted to define at least two positions of the first and second sensing means.

13. An apparatus for measuring linear dimensions of mechanical parts featuring substantially rotational symmetry, comprising:

a support base elongated along a longitudinal direction;

first and second positioning means fixed to the support base for positioning first and second parts, respectively, in longitudinally spaced apart positions;

a first slide movable on the support base along said longitudinal direction;

a second slide and a third slide movable on the first slide along a transverse direction;

first transducer means for providing a signal responsive to the position of the first slide on the support base;

second transducer means for providing a signal responsive to the mutual position of the second and third slides;

first and second sensing means arranged respectively on the second and third slides for selectively cooperating with parts arranged on the first and second positioning means and providing relevant signals;

first motor means coupled to the first slide for moving it along said longitudinal direction and for selectively causing the approach of the first slide towards the first and second positioning means;

second motor means coupled to the second and third slides for selectively causing mutual approach and

moving away displacements of the second and third slides;

whereby dimensions of parts arranged on the first and second positioning means can be selectively measured through displacements of the first, second and third slide to carry the first and second sensing means in cooperation with the part to be measured and through processing of the signals provided by the first and second transducer means with the signals provided by the first and second sensing means.

14. The apparatus according to claim 13, wherein said first and second sensing means respectively comprise a measuring head capable of measuring dimensions along two perpendicular directions.

15. The apparatus according to claim 14, wherein said first and second positioning means define a longitudinal plane of symmetry and said second and third slides and the relevant measuring heads are adapted to be arranged in symmetrical positions with respect to said longitudinal plane of symmetry.

16. The apparatus according to claim 15, wherein said measuring heads have movable arms with feelers adapted to selectively contact the first and second parts, said feelers being adapted to be arranged in positions symmetrical with respect to the first and second positioning means.

* * * * *

United States Patent [19] | [11] Patent Number: 4,833,790
Spencer et al. | [45] Date of Patent: May 30, 1989

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[54] METHOD AND SYSTEM FOR LOCATING AND POSITIONING CIRCULAR WORKPIECES

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[73] Assignee: Lam Research, Fremont, Calif.

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[22] Filed: May 11, 1987

[51] Int. Cl.⁴ G01B 7/31

[52] U.S. Cl. 33/520; 33/549; 33/644

[58] Field of Search .... 33/520, 549, 550, 644, 33/172 E

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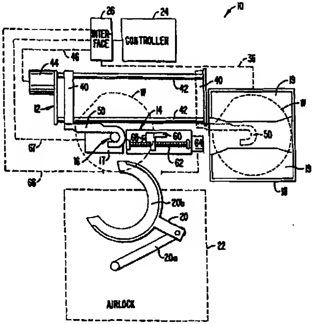
Primary Examiner—William D. Martin, Jr.
Attorney, Agent, or Firm—Townsend & Townsend

[57] ABSTRACT

A system for locating and positioning wafers includes a wafer shuttle, a spindle, and a position sensor. The wafer shuttle retrieves wafers from a storage location, typically a wafer cassette, and transports the wafers to the spindle. The wafers are then incrementally rotated on the spindle, and the distance between the center of rotation and the periphery of the wafer along a linear path is measured. By using three such measurements, the distance and angle with which the center of the wafer is offset from the center of rotation may be calculated. The wafer can then be centered on the spindle by rotation and translated a proper distance by the wafer shuttle. Usually, the wafers will be further rotationally oriented so that the crystal lattice lies in a desired direction.

21 Claims, 2 Drawing Sheets



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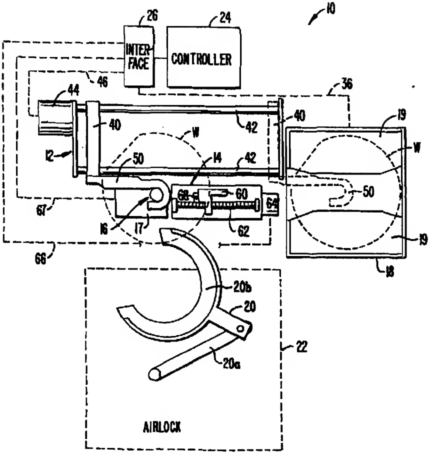
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FIG._1.

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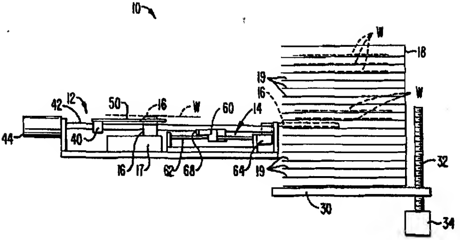
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FIG._2.

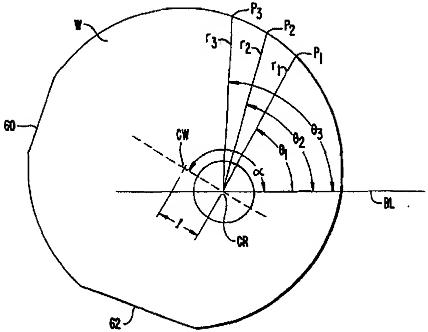
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FIG._3.

METHOD AND SYSTEM FOR LOCATING AND POSITIONING CIRCULAR WORKPIECES

BACKGROUND OF THE INVENTION

The present invention relates generally to systems and methods for the handling of workpieces. More particularly, the invention relates to a system and method for accurately locating and positioning circular workpieces, such as semiconductor wafers.

The need to locate and position circular workpieces can arise under a variety of circumstances. For example,. semiconductor wafer when the retrieved from wafer cassettes are frequently not centered and are randomly oriented with regard to their crystalline lattice structure. Usually, it is necessary to position individual wafers prior to processing, such as plasma etching, chemical vapor deposition, and the like.

Unfortunately, such positioning is problematic. Prior systems have often used either fixed or movable pins to engage the periphery of the wafer and provide some degree of centering. The use of pins, however, is inaccurate, particularly when the wafer being centered has a diameter deviating from the nominal diameter. Moreover, contact with the pins causes substantial generation of particulates which is undesirable in virtually all semiconductor processes. Other systems for locating and aligning semiconductor wafers employ multiple arrays of photosensitive detectors beneath the wafer to locate its periphery. Such systems, however, require a minimum of three detector arrays and are limited by the accuracy with which those arrays may be located. Additionally, these systems require a separate mechanism for correcting the positions of the wafers subsequent to locating them.

For the above reasons, it would be desirable to provide methods and systems which are capable of accurately detecting the positions of circular workpieces, such as semiconductor wafers, and for aligning such workpieces according to preselected criteria. The method and system should be highly accurate, avoid the generation of particulates, and be able to provide true centering regardless of any deviations between the actual and nominal diameters of the wafer. In addition, the system should be relatively simple, inexpensive to build and operate, and be compatible with other material handling and processing systems, such as semiconductor wafer processing systems.

SUMMARY OF THE INVENTION

A system for locating and positioning circular workpieces, particularly semiconductor wafers, prior to subsequent manipulation and processing includes a wafer shuttle, a spindle for rotating the workpieces, and a sensor for measuring the distance between the spindle and the edge of the workpiece mounted on the spindle. The workpieces are retrieved from a remote storage container, typically a wafer cassette, and conveyed along a linear path to the spindle. The workpieces are then secured to the spindle, typically by a vacuum chuck, and incrementally rotated about a fixed center of rotation. The position of the center of the workpiece relative to that of the center of rotation is determined by measuring the distance along the linear path between the center of rotation and the periphery of the workpiece at three different angles of rotation. By applying an appropriate geometric analysis, the angle and length of offset between the center of the wafer and the center of rotation may be determined. The workpiece is then centered on the spindle by first rotating so that the line between the center of rotation and the center of the workpiece are aligned on the linear path and then translating the workpiece along the linear path by a distance equal to the length of offset so that the centers are coincident.

For semiconductor applications, it will frequently be desirable to further rotate the wafers so that their crystal lattice orientation is aligned in a preselected direction. To do so, the wafer is first rotated while the optical sensor locates certain fixed discontinuities in the periphery. Such discontinuities, usually flats and notches, indicate the type and orientation of the crystal structure. The wafer may then be rotated to the desired crystal orientation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic layout of a system for locating and positioning semiconductor wafers constructed in accordance with the principles of the present invention.

FIG. 2 is an elevational view of the system of FIG. 1.

FIG. 3 illustrates the measurements which are made in order to determine the relative positions of the center of rotation and center of the workpiece.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

The following description relates to a system and method for the positioning of semiconductor wafers prior to subsequent manipulation and processing, such as plasma etching, chemical vapor deposition, and the like. Although the description is directed specifically at the handling of semiconductor wafers, it will be appreciated that the principles of the invention apply equally well to handling of other circular workpieces, such as recording disks, magnetic media disks, circular bioassay plates, and the like.

Referring to FIGS. 1 and 2, a positioning system 10 constructed in accordance with the principles of the present invention is illustrated. The system 10 includes a wafer shuttle 12, a position sensor 14, and a rotatable spindle 16 on a base 17. The wafer shuttle 12 is capable of retrieving wafers W from a wafer cassette 18 and transporting the wafers to the spindle 16, as will be described in more detail hereinbelow. Once at the spindle 16, the wafers W are centered and aligned in a desired orientation prior to being removed, typically by an articulated wafer transport arm 20 (including a first segment 20*a* and a cradle segment 20*b* pk capable of supporting individual wafers) which may be located in an airlock 22 asociated with processing equipment, such as a plasma etch system, CVD reactor, or the like. Operation of the wafer shuttle 12, position sensor 14, and rotating spindle 16 are controlled by a central controller 24, typically a programmable digital computer, which communicates through an interface 26 including the necessary analog-to-digital and digital-to-analog converters.

The wafer cassette 18 is a standard cassette comprising a plurality of shelves 19 defining slots capable of receiving individual wafers W and holding them in either vertical or horizontal orientations, depending on the attitude of the cassette. In the present invention, the cassette 18 will be held so that the wafers W lie generally horizontally, with the cassette 18 placed on an elevator platform 30. As schematically illustrated, the

5014

elevator platform 30 is raised and lowered by a rotating screw 32 driven by an electric motor 34. The manner of raising and lowering the cassette 18, of course, is not critical and a wide variety of mechanisms are known and commerically available. It is necessary only that the elevation of the cassette 18 be controllable by the central controller 24, as indicated by communication line 36.

The wafer shuttle 12 includes a carriage 40 mounted to horizontally reciprocate on a pair of guide rails 42. The position of the carriage 40 on the guide rails 42 is controlled by an electric drive motor 44 which is, in turn, controlled by controller 24 as indicated by communication line 46. The manner in which the carriage 40 is driven is not critical, and may comprise a threaded drive shaft, a belt and pulley system, or the like. It is necessary, however, that the drive system be capable of accurately positioning the carriage 40 to within ±0.01 inches, preferably to within ±0.001 inches. The preferred drive system comprises a stepping motor driving a timing belt with a cogged pulley.

A J-shaped support arm 50 is secured to the carriage 40 and reciprocates along a linear path between the spindle 16 and the wafer cassette 18 as the carriage 40 is driven back and forth on the guide rails 42. At the wafer cassette 18, the distal end of the support arm 50 can be inserted beneath a wafer W, usually with a clearance of about 0.01 to 0.10 inches, usually being about 0.045 inches. Once the arm 50 is in position, the wafer cassette 18 can be lowered by lowering platform 30 so that the wafer is lifted off the support slot within the cassette 18. Usually, vacuum ports (not illustrated) will be provided in the support arm 50 for securing the wafer during transport.

After the wafer W has been lifted out of contact with the cassette 18, the wafer may be drawn back toward the spindle 16 by a motor 44 under the supervision of controller 24. The arm 50 is retracted until the J-shaped distal end lies over the spindle 16, as illustrated in full line in FIG. 1. At that time, the spindle 16 is raised (as illustrated in broken line in FIG. 2) so that the wafer W is lifted up from the support arm 50. Usually, the spindle 16 will include a vacuum port for firmly securing the wafer thereto.

At the time when the wafer W is first brought over the spindle 16, the center of rotation of the spindle and the center of the wafer W will normally not be coincident. That is, the center of the wafer W will be offset from the center of the spindle 16 by an unknown distance and in an unknown direction. Although the offset will usually be small, it can be significant in subsequent processing steps. Moreover, the crystal lattice orientation of the wafer W is usually unknown, and it is frequently desirable to provide a particular orientation prior to subsequent processing. The desired centering and rotational orientation of the wafer W may be accomplished as described hereinafter.

The position sensor 14 includes a carriage 60 mounted on a rotating drive screw 62 driven by motor 64. The motor 64 is supervised by controller 24, as indicated by communication line 66. The carriage 60 includes an optical detector 68 mounted thereon. By translating the carriage 60 back and forth on the drive screw 62, the location of the periphery of wafer W along the linear path between the spindle and the cassette may be determined. The type of optical sensor 68 employed is not critical, typically being a light emitting diode (LED) source and a phototransistor detector (not illustrated).

Raising, lowering and rotation of the spindle 16 is also supervised by controller 24 through communication line 67. In this way, rotation of the wafer can be coordinated with the measuring and positioning functions of the system 10.

Referring now to FIG. 3, the distance of offset l and the angle of offset α, between the center of the water CW and center of rotation CR may be determined as follows. The distance r_1 between the center of rotation CR and a point P_1 on the periphery of the wafer W is measured after rotating the wafer through an angle θ_1 from an arbitary baseline BL drawn through the center of rotation. The values of r_1 and θ_1 are then stored in the controller 24. Wafer W is then further rotated through an angle θ_2 relative to the baseline BL and the distance r_2 between the center of rotation CR and a point P_2 on the periphery of the wafer is measured. Similar measurements are then made for point P_3 which is distance r_3 from the center of rotation CR lying on a line displaced from the baseline BL by an angle θ_3. In all cases, the measurement of the distance r is made by the position sensor 14 with the distance r lying along the linear path on which the carriage 60 travels.

Once the measurements just described are completed, the length of offset l and angular offset α may be calculated as follows.

$$\alpha = \tan^{-1}\frac{(r_1\cos\theta_1 - r_3\cos\theta_3) - R(r_1\cos\theta_1 - r_2\cos\theta_2)}{R(r_1\sin\theta_1 - r_2\sin\theta_2) - r_1\sin\theta_1 + r_3\sin\theta_3}$$

wherein $R=(r_1^2-r_3^2)/(r_1^2-r_2^2)$; and

$$l = \frac{r_1^2 - r_2^2}{2((r_1\cos\theta_1 - r_2\cos\theta_2)\cos\alpha + (r_1\sin\theta_1 - r_2\sin\theta_2)\sin\alpha)}.$$

Once the offset angle α and offset length l have been determined, it is an easy matter to center the wafer W so that the center of the wafer CW is aligned with the center of rotation CR of spindle 16. First, the wafer is rotated so that the line between the center of rotation CR and the center of the wafer CW is aligned with the direction of the linear path traveled by support arm 50 of the wafer shuttle 12. The wafer W is then lowered onto the support arm 50 by retracting spindle 16. The support arm 50 is then translated in the direction necessary to align the center of the wafer with the center of rotation. The spindle 16 may then be raised, and the wafer is ready for further manipulation and processing.

In many cases, prior to further manipulation and processing, it will be desirable to rotationally orient the wafer W so that the crystal lattice structure lies in a desired direction. To accomplish this, it is necessary to locate certain flats or notches which are formed on the periphery of the wafer W, as exemplified by flats 60 and 62 illustrated in FIG. 3. The locations of these flats indicate the orientation of the crystal lattice structure within the wafer. The location of the flats may be determined by rotating the wafer W on spindle 16 after the wafer has been centered. The optical sensor 68 is positioned beneath the periphery of the wafer W, and will detect when the periphery appears to fall away due to the presence of a flat or other discontinuity. By storing the locations where the flats begin and end, the controller 24 can determine the precise orientation of the wafer

5015

on the spindle 16. The spindle 16 may then be rotated so that the water W lies in a desired crystal orientation.

Because of the provision of flats and other discontinuities on the periphery of the wafer W, the determination of the offset length l and angular offset α will be incorrect if any of the points P_1–P_3 lie on one of the flats 60 and 62. Thus, it is necessary to check the accuracy of the data generated by the above algorithms. This may be done by determining whether the calculated radius of the wafer (a) is within the expected tolerances for the type of wafer being processed. The radius a may be calculated as follows:

$$a=(r^2+l^2-2rl\cos(\theta-\alpha))^{\frac{1}{2}}$$

where r may be r_1, r_2 or r_3 and θ may be θ_1, θ_2, and θ_3, respectively.

Frequently, even if the calculated radius a is within the expected limits, it will be desirable to recalculate the values of offset length l and angular offset α in order to further confirm the correctness of the original calculations. This can be done using all new data points, or by substituting one or two new data points in the three data points initially utilized. In either case, if the newly calculated values of l and α agree with the originally calculated values, a very high level of confidence in the data is achieved. If the values disagree, if will be necessary to repeat the calculations until agreement is reached.

As just described, the spindle 16 and the optical detector 68 are located on the line of travel of the shuttle support arm 50. Although such configuration is preferred as it simplifies construction and operation of the system, alternative configurations are also available. For example, the spindle 50 could be laterally offset from the line of travel of the shuttle support arm 50, usually by less than one-half the expected diameter of the wafer, more usually by less than one-quarter of said diameter. The line of travel of the optical detector 68 may also be offset, either to lie parallel to the line of travel of the shuttle support arm 50, or to angularly deviate therefrom. Usually, but not necessarily, the line of travel of the optical detector 68 will be aligned with the spindle 16, regardless of the orientation relative to the line of travel of shuttle support arm 50. Such changes in the apparatus may require modification of the algorithms set forth above in order to provide for accurate positioning of the wafers.

The system and method of the present invention as just described have a number of advantages over the prior art. In particular, by contacting the wafers with vacuum pick-ups and only on their rear surfaces, damage to the wafers and the generation of particulates is minimized. Moreover, the system is highly accurate and capable of handling wafers of different diameters without any external changes in the configuration of the system. Finally, the system easily interfaces with conventional wafer handling equipment, such as wafer cassettes and wafer transport arms.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be obvious that certain changes and modifications may be practiced within the scope of the appended claims.

What is claimed is:

1. A system for positioning a circular workpiece, said system comprising:

means for conveying the workpiece along a linear path;

means for rotating the workpiece about a center of rotation located on the linear path;

means for measuring the distance along the linear path between the center of rotation and the periphery of the workpiece; and

means for determining the offset between the center of rotation and the center of the workpiece based on the measured distance between the center of rotation and the periphery of the workpiece at at least three different angles of rotation.

2. A system as in claim 1, wherein the means for determining the offset includes a computer and an interface between the computer and the means for conveying, the means for rotating, and the means for measuring.

3. A system for positioning a circular workpiece, said system comprising:

a cassette capable of holding a plurality of horizontal workpieces arranged in a vertical stack;

means for selecting elevating the cassette;

an arm;

means for reciprocating the arm along a linear path, with the arm extending into the cassette at one end of the path;

means on the arm for detachably securing the workpiece;

means proximate the linear path remote from the cassette for rotating the workpiece about a center of rotation on the linear path;

means for measuring the distance along the linear path between the center of rotation and the periphery of the workpiece; and

means for determining the offset between the center of rotation and the center of the workpiece based on the measured distance between the center of rotation and the periphery of the workpiece at at least three different angles of rotation.

4. A system as in claim 3, wherein the means for reciprocating the arm includes at least one guide rod disposed parallel to the linear path, and means for translating the arm along the guide rod.

5. A system as in claim 3, wherein the means for detachably securing the workpiece includes a vacuum port at a remote end of the arm.

6. A system as in claim 3, wherein the means for rotating the workpiece includes a spindle and the arm includes a J-shaped end which circumscribes the spindle at a preselected position along the linear path.

7. A system for positioning a circular workpiece, said system comprising:

means for conveying the workpiece along a linear path;

a spindle located proximate the path;

means on the spindle for detachably securing the workpiece;

means for selectively elevating and rotating the spindle, whereby the workpiece may be secured, raised from the conveying means, and rotated through a desired angle;

means for measuring the distance along a line between the center of rotation and the periphery of the workpiece; and

means for determining the offset between the center of rotation and the center of the workpiece baesd on the measured distance between the center of

rotation and the periphery of the workpiece at at least three different angles of rotation.

8. A system as in claim 7, wherein the center of rotation is located on the linear path.

9. A system as in claim 7, wherein the distance between the center of rotation and the periphery of the workpiece is measured along the linear path.

10. A system as in claim 7, wherein the means for detachably securing the workpiece includes a vacuum port.

11. A system as in claim 7, wherein the spindle is a cylindrical shaft having a vacuum port at one end.

12. A system as in claim 11, wherein the means for selectively elevating and rotating the spindle includes a controllable motor connected to rotate the spindle.

13. A system for positioning a circular workpiece, said system comprising:

means for conveying the workpiece along a linear path to a first location;

means at said first location for raising the workpiece from the means for conveying and for rotating the workpiece about a center of rotation;

a position sensor;

means for reciprocating a position sensor along at least a portion of the linear path, whereby the distance between the center of rotation and the periphery of the workpiece may be measured; and

means for determining the angular deviation (α) between the linear path and a line drawn through the center of the workpiece and the center of rotation and the linear distance (l) between the center of the workpiece and the center of rotation based on the measured distance between the center of rotation and the periphery of the workpiece at at least three different angles of rotation.

14. A system as in claim 13, wherein the position sensor is an optical sensor.

15. A system as in claim 13, wherein the means for reciprocating the position sensor includes a drive screw and a carriage mounted on the drive screw.

16. A system as in claim 13, further including a controllable motor connected to rotate the drive screw.

17. A method for positioning a circular workpiece, said method comprising:

incrementally rotating the workpiece about a fixed center of rotation where the center of rotation and the center of the workpiece are not coincident;

measuring the distance between the center of rotation and the periphery of the workpiece at at least three different angles of rotation; and

determining angular deviation (α) between an arbitrary baseline drawn through the center of rotation and a line drawn through the center of the workpiece and the center of rotation and the linear distance (l) between the center of the workpiece and the center of rotation, based on said measured distances; and

positioning the workpice by rotating through angle α and translating through distance l so that the center of the workpiece and the center of rotation are aligned.

18. A method as in claim 17, further including the following steps which are performed after the center of the workpiece and center of rotation are aligned:

rotating the workpiece to detect discontinuities in its circular periphery; and

rotationally positioning the workpiece so that the discontinuities are rotationally aligned in a preselected pattern.

19. A method as in claim 17, wherein measurement between the center of rotation and the periphery of the workpiece is repeated to confirm the determination of angular deviation α and distance l.

20. A method as in claim 17, wherein the angular deviation α is determined by the following algorithm:

$$\alpha = \tan^{-1}\frac{(r_1\cos\theta_1 - r_3\cos\theta_3) - R(r_1\cos\theta_1 - r_2\cos\theta_2)}{R(r_1\sin\theta_1 - r_2\sin\theta_2) - r_1\sin\theta_1 + r_3\sin\theta_3}$$

wherein:

r_1 is the distance between the center of rotation and a point on the periphery of the workpiece when the workpiece is rotated by angle θ_1 from the baseline;

r_2 is the distance between the center of rotation and a point on the periphery of the workpiece when the workpiece is rotated by angle θ_2 from the baseline;

r_3 is the distance between the center of rotation and a point on the periphery of the workpiece when the workpiece is rotated by angle θ_3 from the baseline; and

$$R=(r_1^2-r_3^2)/(r_1^2-r_2^2).$$

21. A method as in claim 20, wherein the length l of offset is determined by the following algorithm:

$$l = \frac{r_1^2 - r_2^2}{2((r_1\cos\theta_1 - r_2\cos\theta_2)\cos\alpha + (r_1\sin\theta_1 - r_2\sin\theta_2)\sin\alpha)}.$$

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US005205046A

United States Patent [19]

Barnett et al.

[11] Patent Number: 5,205,046

[45] Date of Patent: Apr. 27, 1993

[54] METHOD FOR MEASURING SURFACE WAVINESS

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[73] Assignee: Ford Motor Company, Dearborn, Mich.

[21] Appl. No.: 711,488

[22] Filed: Jun. 5, 1991

[51] Int. Cl.[5] G01D 5/20

[52] U.S. Cl. 33/533; 33/556

[58] Field of Search 33/533, 600, 679.1, 33/566, 485, 486, 487, 489, 533, 554, 555, 551, 503; 73/159

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Primary Examiner—William A. Cuchlinski, Jr.
Assistant Examiner—William C. Dowling
Attorney, Agent, or Firm—Daniel M. Stock; Clifford L. Sadler

[57] ABSTRACT

A method an apparatus for simply and inexpensively objectively measuring the waviness of a panel such as an automotive sheet metal panel utilizes a digital flushness gauge mounted on a fixture to slide in planar fashion over a surface. Depth readings are taken at regular increments along a scaled axis, and the absolute value of differences between succeeding readings is computed to yield an indication of the degree of waviness resulting from the total slope change over the length through which readings are taken.

3 Claims, 2 Drawing Sheets

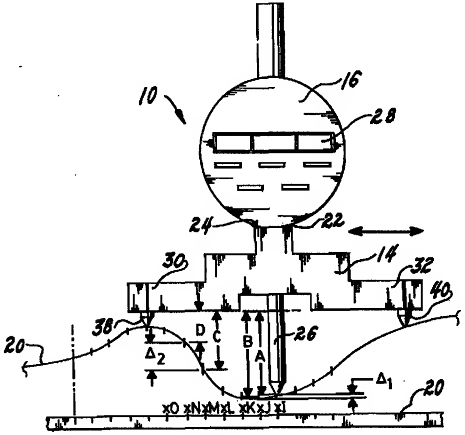

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EXHIBIT 7

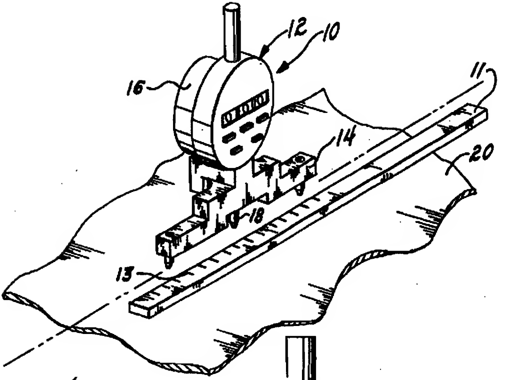

Fig. 1

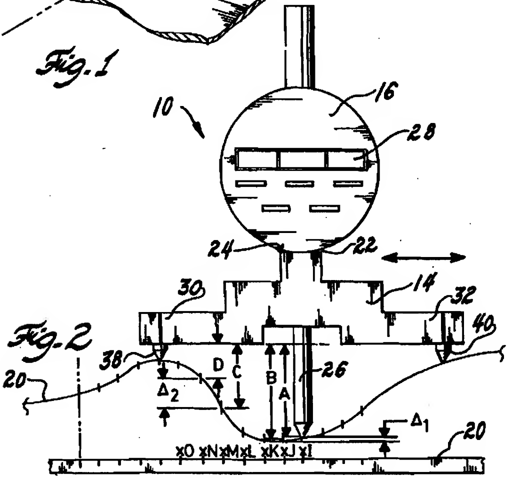

Fig. 2

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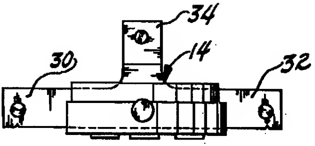

Fig. 4

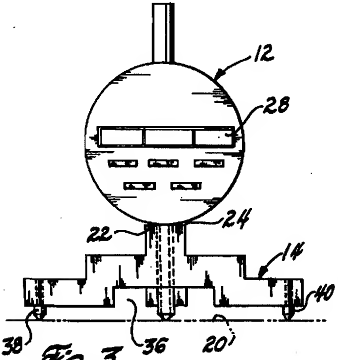

Fig. 3

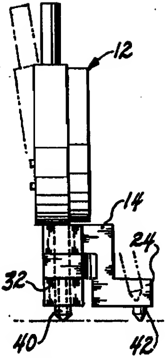

Fig. 5

METHOD FOR MEASURING SURFACE WAVINESS

BACKGROUND OF THE INVENTION

The present invention relates generally to the mechanical measurements of surfaces and, more specifically, to measurement of waviness in product surfaces, such as sheet metal and window glass.

In manufacturing external surface components of an automotive vehicle, controlling the quality of the surface finish is an important consideration. Without regard to the acceptability of the function of a component itself, a component that displays an external surface that is aesthetically unpleasing is often viewed by consumers as a product lacking in quality. Two criteria for judging the aesthetic acceptability of a sheet metal panel relate to the absence of roughness and waviness in the panel. Roughness may be defined for convenience here as microscopic changes in the slope of the surface. "Orange peel" conditions in the painted surface are one example of an unacceptable rough surface on a sheet metal panel. A depression or "streamer" formed in a sheet metal panel during a drawing operation during the stamping of the panel, on the other hand, results in larger macroscopic changes in the slope of the surface defined by that operation. This is waviness. Any surface variation that becomes visible to a consumer when the surface waves are sufficient to cause discontinuities in the reflection of light is an unacceptable level of waviness.

While techniques for measuring roughness are relatively well-developed, the measurement of waviness remains a largely subjective practice dependent at least in part on the visual perception of a wide variety of inspectors. Certain direct measurement techniques are available, however. Among them, the use of expensive profilometers to provide a magnified plot on scaled paper of the profile of a surface. The device is used in conjunction with a reference of the intended design curve of the part itself. Computer aided design data or blueprint information must be compared to the readings of the profilometer and charted for deviations. This is a slow and time-consuming process that cannot effectively be used with great frequency in a high volume production environment such as is encountered in the automotive industry. The recording of a sufficient number of profile data points to define the part's shape for comparison with the intended design also require subjective evaluation of the comparison, tending to dilute its effectiveness. The method utilizing profilometer measurements for evaluating sheet metal panel waviness suffers from the additional defect that it inherently measures absolute values from some fixed base line that is calibrated to the shape of the intended design. Each individual deviation from that base line shape definition must be individually analyzed to determine what effect the deviations have on the aesthetic perception of waviness.

The prior art teaches the use of another mechanism for determining waviness that suffers from the last mentioned defect in that it works about a fixed reference in U.S. Pat. No. 3,470,739 to Takafuji et al.

SUMMARY OF THE INVENTION

Responsive to the deficiencies in the prior art, it is an object of the present invention to provide a method and apparatus for measuring surface waviness in a panel that functions without the use of a calibrated base line.

It is another object of the invention to provide such a method and apparatus which is readily adaptable to high volume production.

It is still another object of the present invention to provide such a method and apparatus that is objective in result not requiring subjective interpretation of esthetic values with respect to the surface.

It is yet another object of the present invention to provide an apparatus which is economically producible and readily adaptable to use in large scale manufacturing facilities.

According to the invention, a digital flushness gauge is mounted on a fixture axially movable along the surface to be measured, the gauge being operated to take sample readings at incremental distances during that movement. The sequential readings are compared and differences between adjacent readings are utilized to yield the local waviness difference. The absolute values of these local differences are summed to create a "waviness index" number.

According to another feature of the present invention, a fixture is provided for holding the digital flushness gauge which defines a plane for positioning the gauge with respect to the measured panel, thereby minimizing the variations in measurement attendant the change in operators of the equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features will be apparent to those skilled in the measurement arts upon reading the following description with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of an apparatus according to the present invention in use for measurement of a panel.

FIG. 2 is a diagrammatic view of the apparatus of the present invention illustrating its measurement of a surface.

FIG. 3 is a front view of the apparatus of the present invention.

FIG. 4 is a top view of the apparatus.

FIG. 5 is a side view of the apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The waviness measurement apparatus 10 of the present invention is illustrated as comprising a digital flushness gauge 12 and a fixture 14. The digital flushness gauge 12 is illustrated as comprising a readout module 16 operatively connected to a probe 18 engageable and vertically displaceable in contact with a surface 20 to be measured, as may best be seen in FIGS. 1 and 2.

The flushness gauge 12 can utilize any of a number of depth measuring devices. One example of a device that can be used as the digital flushness gauge 12 is that manufactured by Mitutoyo Corporation as its Model 543-182. With that particular gauge, the probe 18 includes a mounting portion 22 which shoulders against an upper surface 24 of the fixture 14. The operative measurement portion 26 of the probe 18 depends below the fixture 14 and is vertically movable, as may best be seen in FIG. 2. As the measurement portion 26 moves vertically in response to changes in the surface 20, the digital flushness gauge 12 is operative to display suitable numerical indicia on the screen indicated at 28.

The fixture 14 is preferably formed as a unitary structure fabricated by precision machining to define three feet 30, 32, 34 spanning a raised central portion 36 from which the measuring portion 26 of the digital flushness gauge 12 depends. Mounting pins 38, 40, 42 depend from the feet 30, 32, 34, respectively, are smooth and coplanar, thereby defining a plane for orientation of the axial movement of the measurement portion 26 of the digital flushness gauge 12.

According to one preferred embodiment of the Present invention, the fixture 14 is fabricated from tool steel and is 110 mm long from the end of the foot 30 to the end of the foot 32 and is 29.5-mm wide from the distal end of the foot 34 to the opposed edges of the feet 30, 32.

As can be seen in FIG. 2, it is intended, according to the present invention that the apparatus 10 further includes a measurement template 11, which need be of no particular configuration, merely providing a linear scale marked as indicated at 131, along which the apparatus 10 is moved. It may, however, be smooth edged and fixed to the surface 20 for guiding movement of the fixture 14.

The method of using the apparatus 10, according to the present invention, can be well appreciated by reference to FIG. 2. The apparatus 10 is placed in confronting relationship with the surface 20 of a sheet metal panel oriented as shown in FIG. 1. The feet 30, 32, 34 engage the panel through pins 38, 40, 42, and the probe 18 is vertically displaced to yield a reading on the screen 28 indicative of the position of the probe 18 with respect to the plane defined by the feet 30, 32, 34. Fixture 14 is then moved along the panel along the axis of the template 11 at regular increments indicated by the indicia XI, XJ, XR . . . , and readings are displayed on the screen 28 for each of these positions, each representing a position of the probe with respect to the plane defined by the fixture 14 when moved to the position corresponding to the increment on the measurement template 11. Since the incremental changes along the axis parallel to the measurement template are fixed, the changes between each consecutive reading by the probe 18 are indicative of the slope between these two points. Consistency in readings is enhanced by the three-point definition of the fixture plane. It will be appreciated, however, that the tips of the mounting pins may be configured to accommodate some third leg tipping, as is illustrated in exaggerated fashion in FIG. 3. The waviness of a particular panel can be evaluated by sequentially subtracting each prior reading from each subsequent reading and recording the difference throughout a desired length of the template, such as 150 mm at 10 mm increments. Summing the absolute value of these differences is then effected to yield a "waviness index" number. The larger number of this summation is the greater the total sensed slope change and the wavier the surface. Utilizing this method with the simple apparatus described provides a repeatable, inspector-insensitive technique technique for determining the waviness of a panel.

While only one embodiment of the method and apparatus of the present invention are here described, others may be possible without departing from the scope of the appended claims. For example, a multiplicity of probes could be fixtured for effecting simultaneous collection of a number of readings; and automated gauge movement and data recording and computation techniques could be utilized.

We claim:

1. A method of determining the waviness of a panel comprising:

providing a fixture defining a flat planar surface;

mounting a depth measuring gauge on the fixture;

moving the fixture and the mounted gauge into confronting relationship with the panel at a first position;

operating the gauge to measure the depth of the panel with respect to the planar surface;

sliding the fixture along a predetermined axis to a plurality of subsequent positions spaced from each other and from the first position in a predetermined sequential relationship;

repeating the operating and measuring step at each of the subsequent positions;

computing the difference between each measurement and the measurement at the directly subsequent position to each measurement; and

computing the absolute value of the differences as an indication of the waviness of the panel.

2. A method as defined in claim 1 and further comprising providing a template and arranging the template with respect to the panel to define the predetermined axis and the predetermined sequential sliding movement of the fixture.

3. A method as defined in claim 2 and further comprising fixedly securing the template with respect to the panel.

* * * * *

US005433013A

United States Patent [19]

Woodhouse

[11] Patent Number: 5,433,013

[45] Date of Patent: Jul. 18, 1995

D

[54] FIXTURE FOR ALIGNMENT OF VACUUM NOZZLES ON SEMICONDUCTOR MANUFACTURING EQUIPMENT

[75] Inventor: Glenn P. Woodhouse, Boise, Id.

[73] Assignee: Micron Custom Manufacturing Services, Inc., Boise, Id.

[21] Appl. No.: 126,824

[22] Filed: Sep. 24, 1993

[51] Int. Cl.[6] G01B 5/252; B21C 51/00

[52] U.S. Cl. 33/533; 33/550; 33/555; 72/34

[58] Field of Search .... 33/533, 546, 549, 550, 33/555, 506, DIG. 2, DIG. 8; 72/370, 31, 34; 29/337, DIG. 41

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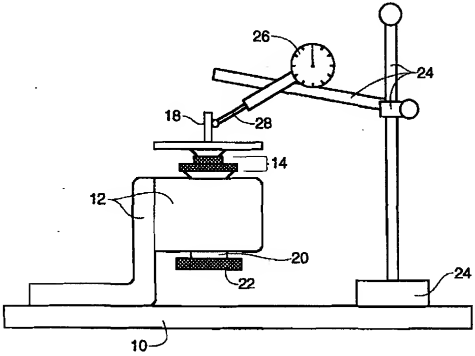
Primary Examiner—Alvin Wirthlin

Attorney, Agent, or Firm—Kevin D. Martin

[57] ABSTRACT

An apparatus for measuring and correcting the straightness of a hollow vacuum nozzle for semiconductor assembly equipment comprises a collet which can rotate over 360° and holds the nozzle. An indicator, such as a dial indicator, has a tip which conformally and continuously engages the nozzle so that as the collet and nozzle are rotated the indicator tip rides on the nozzle. Any horizontal movement of a bent nozzle is shown on the indicator. The bend in the nozzle can then be repaired and rechecked while the nozzle is installed in the collet.

5 Claims, 2 Drawing Sheets



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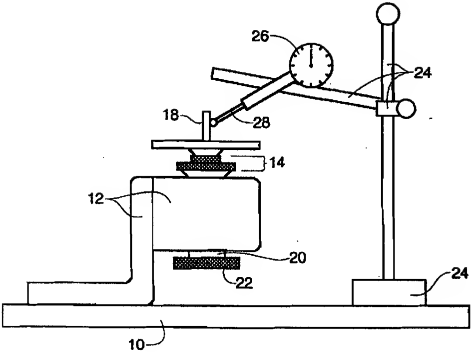

FIG. 1

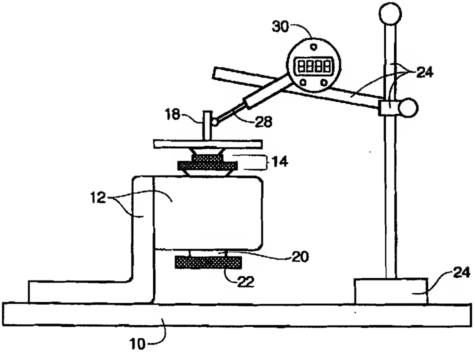

FIG. 2

FIXTURE FOR ALIGNMENT OF VACUUM NOZZLES ON SEMICONDUCTOR MANUFACTURING EQUIPMENT

FIELD OF THE INVENTION

The invention relates to the field of printed circuit assembly manufacturing, and more specifically to the repair of equipment used to assemble semiconductor devices onto printed circuit boards.

BACKGROUND OF THE INVENTION

To assemble components such as memory devices, logic devices, and other integrated circuits onto printed circuit boards, an automated process is commonly used. One link in the automated assembly process is a pick and place machine such as the IP-II manufactured by Fuji of Chiryn, Aichiken, Japan. The pick and place machine uses an X-Y positioning system and a motorized hollow vacuum nozzle to remove the memory device(s) or integrated circuit(s) from a tape and reel feeder, stick feeder, or waffle tray and place the devices on the printed circuit board in the correct X, Y, and rotational position. A properly functioning pick and place machine such as the Fuji described above can accurately place devices to a tolerance of ±0.004 inches.

One problem associated with the vacuum nozzle is that through use the nozzle can become bent which greatly decreases the placement accuracy of the machine. To fully calibrate the pick and place machine each nozzle must be properly aligned. On the Fuji IP-II there are eight nozzles. Bent nozzles are typically returned to the factory for reconditioning or replacement which requires a number of weeks and a high expense. There is a need for an apparatus which allows for a quick and economical repair of bent nozzles.

SUMMARY OF THE INVENTION

The apparatus described herein is used for measuring the bend or straightness of a hollow vacuum nozzle for semiconductor assembly equipment. The apparatus, in one embodiment, comprises a distance indicator and an indicator tip movably attached (adjacent) to the distance indicator. The indicator tip continuously and conformally engages the hollow vacuum nozzle. The apparatus further comprises a collet capable of rotating 360° for receiving the hollow vacuum nozzle. The apparatus is arranged such that as the collet and the nozzle are rotated the indicator tip rides on the nozzle and the indicator indicates the position of the indicator tip.

Objects and advantages will become apparent to those skilled in the art from the following detailed description read in conjunction with the appended claims and the drawings attached hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of one embodiment of the apparatus; and

FIG. 2 is a side view of a second embodiment of the invention comprising an electronic indicator.

It should be emphasized that the drawings herein are not necessarily to scale but are merely schematic representations. Specific structural details can be determined by one of skill in the art by examination of the drawing along with the information herein.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a side view of one embodiment of the invention. In this embodiment, the various elements are positioned on a base 10. A first element comprises a bracket 12 mounted to the base 10. The bracket 12 receives an interchangeable collet 14, and the collet 14 receives a hollow nozzle 18. In the embodiment shown, the collet 14 is similar to the collet found on the Fuji IP-II pick and place, although other collets would function sufficiently due to the ability of the bracket to receive various collets. The IP-II requires two different types of nozzles so in this embodiment the apparatus has two interchangeable collets to receive them. The collet 14 is positioned on a set of bearings (not shown) and an axle 20 connects the collet 14 to a bottom wheel 22 through the bracket 12. The bottom wheel 22 facilitates rotation of the collet 14, for example by an equipment technician, and the collet is such that it can rotate the nozzle 360°. The collet 14 receives the hollow nozzle 18.

Also positioned on the base is a magnetic dial indicator stand 24 which receives a dial indicator 26 having, for example, a spring loaded indicator tip 28. The indicator tip 28 continuously and conformally engages the hollow vacuum nozzle 18 such that as the collet 14 and the nozzle 18 are rotated the indicator tip 28 rides on the nozzle 18 and the indicator 26 indicates the position of the tip 28.

A straight nozzle tested using the apparatus will rotate about its center point, and thus the indicator will remain on a single setting. A bent nozzle, however, will rotate about an axis away from its center point and thus the indicator will change with the rotation of the nozzle. In other words, a bent rotating nozzle moves the indicator tip horizontally and is measured by the indicator, while a straight rotating tip will have no horizontal movement. If the indicator shows that a nozzle is bent, a technician can manually straighten the nozzle, retest it, and provide further adjustment if necessary. A small rod was used to aid in straightening a bent nozzle. It was found that the nozzle was sufficiently straightened by placing a small rod into the end of the hollow vacuum nozzle and using the rod as a lever to straighten the nozzle. The fixture as shown in FIG. 1 provided sufficient support to allow the technician to straighten the nozzle while it was mounted in the fixture. With the invention as described above, a bend of as little as 0.001 inches was detected and repaired. As the maximum detectable bend depends on the length of the tip and the resolution of the indicator, the apparatus can be adjusted to allow for the maximum allowable bend.

The indicator used was a dial indicator manufactured by Teclock Corporation of Japan, model number LT-310, although many other indicators, mechanical 26 (as shown in FIG. 1) or electronic 30 (as shown in FIG. 2), would function sufficiently. The magnetic indicator stand was a model number 657 manufactured by Starrett of Athol, Mass. The collets for the nozzle were manufactured of steel by an in house machine shop. The bracket for the collet was manufactured of aluminum and the base was steel, and each was manufactured by an in-house machine shop.

While this invention has been described with reference to illustrative embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the illustrative embodiments, as well as additional embodiments of the invention, will be appar-

ent to persons skilled in the art upon reference to this description. For example, various embodiments of the invention can be used to repair other workpieces such as other types of nozzles or tubes or pipes. It is therefore contemplated that the appended claims will cover any such modifications or embodiments as fall within the true scope of the invention.

What is claimed is:

1. A method for straightening a bend of a hollow vacuum nozzle for semiconductor assembly equipment, comprising the following steps:

a) providing a distance indicator;

b) providing a 360° rotatable collet:

c) placing a hollow vacuum nozzle into said collet;

d) providing an indicator tip movably attached to said distance indicator, said indicator tip continuously and conformally engaging said hollow vacuum nozzle;

e) rotating said collet and said nozzle such that said tip rides on said nozzle, said indicator indicating the position of said indicator tip;

f) placing a rod into an exposed end of said hollow vacuum nozzle and bending said hollow vacuum nozzle responsive to said indication on said indicator, said collet supporting said nozzle during said bending.

2. The method of claim 1, wherein step e) is repeated.

3. The method of claim 1 wherein during step e) said indicator indicates horizontal movement of said nozzle.

4. The method of claim 1 wherein said indicator is a dial indicator.

5. The method of claim 1 wherein said indicator is an electronic indicator.

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US005539992A

United States Patent [19]

Woodhouse

[11] **Patent Number: 5,539,992**

[45] **Date of Patent: *Jul. 30, 1996**

[54] **FIXTURE FOR ALIGNMENT OF VACUUM NOZZLES ON SEMICONDUCTOR MANUFACTURING EQUIPMENT**

[75] Inventor: **Glenn P. Woodhouse**, Boise, Id.

[73] Assignee: **Micron Electronics, Inc**, Nampa, Id.

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,433,013.

[21] Appl. No.: **421,707**

[22] Filed: **Apr. 12, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 126,824, Sep. 24, 1993, Pat. No. 5,433,013.

[51] **Int. Cl.**^{6} **G01B 5/252**; B21C 51/00

[52] **U.S. Cl.** **33/533**; 33/550; 33/555; 72/31.05

[58] **Field of Search** 33/533, 546, 549, 33/550, 555; 29/337; 72/31.04, 31.05

[56] **References Cited**

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4,679,330	7/1987	Williams	33/550
5,253,499	10/1993	Knipp et al.	72/34
5,301,436	4/1994	Johnston	33/506

OTHER PUBLICATIONS

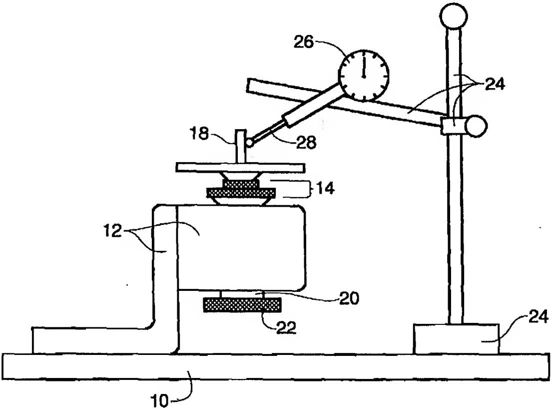
Woodworth Catalog Z-54, *Zero Spindle Inspection Fixtures*, 1956. No Month.

Primary Examiner—Thomas B. Will
Attorney, Agent, or Firm—Kevin D. Martin

[57] **ABSTRACT**

An apparatus for measuring and correcting the straightness of a hollow vacuum nozzle for semiconductor assembly equipment comprises a collet which can rotate over 360° and holds the nozzle. An indicator, such as a dial indicator, has a tip which conformally and continuously engages the nozzle so that as the collet and nozzle are rotated the indicator tip rides on the nozzle. Any horizontal movement of a bent nozzle is shown on the indicator. The bend in the nozzle can then be repaired and rechecked while the nozzle is installed in the collet.

19 Claims, 2 Drawing Sheets



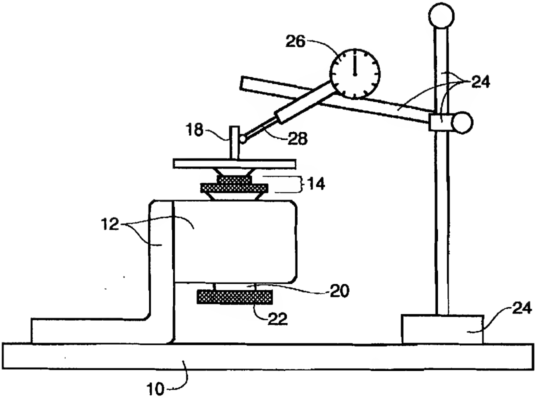


FIG. 1

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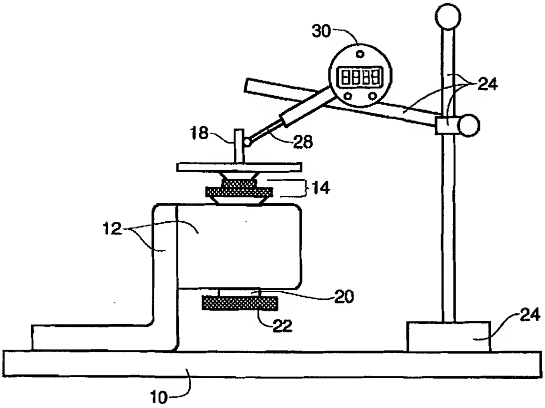

FIG. 2

5030

FIXTURE FOR ALIGNMENT OF VACUUM NOZZLES ON SEMICONDUCTOR MANUFACTURING EQUIPMENT

This is a continuation of application Ser. No. 08/126,824, filed on Sep. 24, 1993, now U.S. Pat. No. 5,433,013.

FIELD OF THE INVENTION

The invention relates to the field of printed circuit assembly manufacturing, and more specifically to the repair of equipment used to assemble semiconductor devices onto printed circuit boards.

BACKGROUND OF THE INVENTION

To assemble components such as memory devices, logic devices, and other integrated circuits onto printed circuit boards, an automated process is commonly used. One link in the automated assembly process is a pick and place machine such as the IP-II manufactured by Fuji of Chiryu, Aichiken, Japan. The pick and place machine uses an X-Y positioning system and a motorized hollow vacuum nozzle to remove the memory device(s) or integrated circuit(s) from a tape and reel feeder, stick feeder, or waffle tray and place the devices on the printed circuit board in the correct X, Y, and rotational position. A properly functioning pick and place machine such as the Fuji described above can accurately place devices to a tolerance of ±0.004 inches.

One problem associated with the vacuum nozzle is that through use the nozzle can become bent which greatly decreases the placement accuracy of the machine. To fully calibrate the pick and place machine each nozzle must be properly aligned. On the Fuji IP-II there are eight nozzles. Bent nozzles are typically returned to the factory for reconditioning or replacement which requires a number of weeks and a high expense. There is a need for an apparatus which allows for a quick and economical repair of bent nozzles.

SUMMARY OF THE INVENTION

The apparatus described herein is used for measuring the bend or straightness of a hollow vacuum nozzle for semiconductor assembly equipment. The apparatus, in one embodiment, comprises a distance indicator and an indicator tip movably attached (adjacent) to the distance indicator. The indicator tip continuously and conformally engages the hollow vacuum nozzle. The apparatus further comprises a collet capable of rotating 360° for receiving the hollow vacuum nozzle. The apparatus is arranged such that as the collet and the nozzle are rotated the indicator tip rides on the nozzle and the indicator indicates the position of the indicator tip.

Objects and advantages will become apparent to those skilled in the art from the following detailed description read in conjunction with the appended claims and the drawings attached hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of one embodiment of the apparatus; and

FIG. 2 is a side view of a second embodiment of the invention composing an electronic indicator.

It should be emphasized that the drawings herein are not necessarily to scale but are merely schematic representations. Specific structural details can be determined by one of skill in the art by examination of the drawing along with the information herein.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a side view of one embodiment of the invention. In this embodiment, the various elements are positioned on a base 10. A first element comprises a bracket 12 mounted to the base 10. The bracket 12 receives an interchangeable collet 14, and the collet 14 receives a hollow nozzle 18. In the embodiment shown, the collet 14 is similar to the collet found on the Fuji IP-II pick and place, although other collets would function sufficiently due to the ability of the bracket to receive various collets. The IP-II requires two different types of nozzles so in this embodiment the apparatus has two interchangeable collets to receive them. The collet 14 is positioned on a set of bearings (not shown) and an axle 20 connects the collet 14 to a bottom wheel 22 through the bracket 12. The bottom wheel 22 facilitates rotation of the collet 14, for example by an equipment technician, and the collet is such that it can rotate the nozzle 360°. The collet 14 receives the hollow nozzle 18.

Also positioned on the base is a magnetic dial indicator stand 24 which receives a dial indicator 26 having, for example, a spring loaded indicator tip 28. The indicator tip 28 continuously and conformally engages the hollow vacuum nozzle 18 such that as the collet 14 and the nozzle 18 are rotated the indicator tip 28 rides on the nozzle 18 and the indicator 26 indicates the position of the tip 28.

A straight nozzle tested using the apparatus will rotate about its center point, and thus the indicator will remain on a single setting. A bent nozzle, however, will rotate about an axis away from its center point and thus the indicator will change with the rotation of the nozzle. In other words, a bent rotating nozzle moves the indicator tip horizontally and is measured by the indicator, while a straight rotating tip will have no horizontal movement. If the indicator shows that a nozzle is bent, a technician can manually straighten the nozzle, retest it, and provide further adjustment if necessary. A small rod was used to aid in straightening a bent nozzle. It was found that the nozzle was sufficiently straightened by placing a small rod into the end of the hollow vacuum nozzle and using the rod as a lever to straighten the nozzle. The fixture as shown in FIG. 1 provided sufficient support to allow the technician to straighten the nozzle while it was mounted in the fixture. With the invention as described above, a bend of as little as 0.001 inches was detected and repaired. As the maximum detectable bend depends on the length of the tip and the resolution of the indicator, the apparatus can be adjusted to allow for the maximum allowable bend.

The indicator used was a dial indicator manufactured by Teclock Corporation of Japan, model number LT-310, although many other indicators, mechanical 26 (as shown in FIG. 1) or electronical 30 (as shown in FIG. 2) would function sufficiently. The magnetic indicator stand was a model number 657 manufactured by Starrett of Athol, Mass. The collets for the nozzle were manufactured of steel by an in house machine shop. The bracket for the collet was manufactured of aluminum and the base was steel, and each was manufactured by an in-house machine shop.

While this invention has been described with reference to illustrative embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the illustrative embodiments, as well as additional embodiments

of the invention, will be apparent to persons skilled in the art upon reference to this description. For example, various embodiments of the invention can be used to repair other workpieces such as other types of nozzles, tubes or pipes. It is therefore contemplated that the appended claims will cover any such modifications or embodiments as fall within the true scope of the invention.

What is claimed is:

1. A method for straightening a tube, comprising the following steps:

a) providing a distance indicator;

b) providing a collet;

c) placing a tube into said collet;

d) providing an indicator tip which indicates a position of said tube;

e) rotating said collet thereby rotating said tube, said indicator indicating a position of said tube;

f) straightening said tube with a rod responsive to said indication, said collet supporting said tube during said straightening.

2. The method of claim 1, wherein said step of rotating said collet is repeated after said step of straightening said tube.

3. The method of claim 1 wherein during said step of rotating said collet, said indicator indicates horizontal movement of said tube.

4. The method of claim 1 further comprising the step of providing a bracket which positions said collet with respect to said indicator tip.

5. The method of claim 1 wherein said tube is a nozzle for semiconductor assembly equipment.

6. The method of claim 1 wherein said tube has a hollow portion therein, and said method further comprises the step of placing said rod into said hollow portion and straightening said tube responsive to said indication on said indicator.

7. A method for bending a workpiece, comprising the following steps:

a) providing a distance indicator;

b) providing a collet;

c) placing a workpiece into said collet;

d) moving said collet thereby moving said workpiece, such that said indicator indicates a position of said workpiece;

e) bending said workpiece responsive to said indication of said workpiece position.

8. The method of claim 7 wherein said collet supports said workpiece during said bending.

9. The method of claim 7 wherein during said step of moving said collet, said indicator indicates horizontal movement of said workpiece.

10. The method of claim 7 further comprising placing a rod into a hollow end of said workpiece during said bending step.

11. The method of claim 7 further comprising the step of straightening said workpiece during said bending step.

12. The method of claim 7 wherein said workpiece is a nozzle for semiconductor assembly equipment.

13. The method of claim 7 wherein said collet is replaceable.

14. The method of claim 7, further comprising using a rod to aid in bending said workpiece responsive to said indication.

15. The method of claim 7 wherein said workpiece has a hollow portion therein, and said method further comprises the step of placing a rod into said hollow portion and straightening said workpiece during said bending step.

16. A method for straightening a bend of a hollow vacuum nozzle for semiconductor assembly equipment, comprising the following steps:

a) providing a distance indicator;

b) providing a rotatable collet;

c) placing a hollow vacuum nozzle into said collet;

d) providing an indicator tip movably attached to said distance indicator, said indicator tip engaging said hollow vacuum nozzle;

e) rotating said collet and said nozzle, said tip riding on said nozzle such that said indicator tip indicates the position of said nozzle;

f) placing a rod into an exposed end of said hollow vacuum nozzle and bending said hollow vacuum nozzle responsive to said indication on said indicator, said collet supporting said nozzle during said bending step.

17. The method of claim 16 wherein said collet is rotatable through 360°.

18. The method of claim 16 wherein said step of rotating said collet is repeated.

19. The method of claim 16 wherein during said step of rotating said collet and said nozzle, said collet is rotated which thereby rotates said nozzle.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,539,992

DATED : July 30, 1996

INVENTOR(S) : Glenn P. Woodhouse

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Column 1, line 64, please replace "composing" with — comprising —.

Column 2, line 57, please replace "electronical" with — electronic —.

Column 3, line 43, after "collet", please insert — , — (a comma).

Signed and Sealed this

Seventeenth Day of December, 1996

Attest:

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

F

US005639953A

United States Patent [19]

Renslow

[11] **Patent Number: 5,639,953**

[45] **Date of Patent: Jun. 17, 1997**

[54] **ALIGNMENT VERIFICATION DEVICE FOR A ROTATING SHAFT**

[75] Inventor: **Bruce E. Renslow**, Castaic, Calif.

[73] Assignee: **Hanson Research Corporation**, Chatsworth, Calif.

[21] Appl. No.: **607,243**

[22] Filed: **Feb. 26, 1996**

[51] **Int. Cl.**^{6} **G01B 5/252**

[52] **U.S. Cl.** **73/1.73**; 33/533; 73/1.01

[58] **Field of Search** .... 73/1 J, 1 E, 1 R; 33/545, 546, 792, 806, 828, 832–836, 533

[56] **References Cited**

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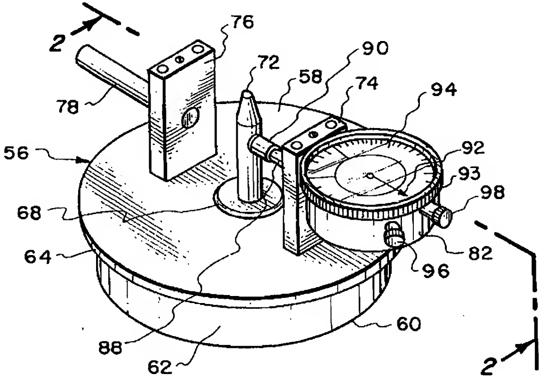
Primary Examiner—Robert Raevis
Attorney, Agent, or Firm—Jack C. Munro

[57] **ABSTRACT**

An alignment verification device for a rotating shaft that utilizes a calibration adapter assembly that has a longitudinal center axis. Mounted on the calibration adapter assembly in a concentric manner is a dial indicator. The stem of the dial indicator is to be placed against a precisely manufactured alignment shaft which has been temporarily substituted for a rotating shaft whose axis of rotation is to coincide with the longitudinal center axis of the calibration adapter assembly. Rotational relative movement between the stem and the shaft will produce readings on the dial indicator with any deviations of the axis of rotation from the longitudinal center axis being discovered by the dial indicator. A zeroing mechanism is to be utilized in conjunction with the calibration adapter assembly prior to connection with the rotating shaft. The zeroing mechanism takes the form of a gauge plug which is to be mounted in a close tolerance manner within a through hole formed within the calibration adapter assembly. The gauge plug has a protruding rod whose longitudinal center axis coincides with the longitudinal axis of the calibration adapter assembly. The stem of the dial indicator is to contact the protruding rod and upon rotational relative movement between the stem and the protruding rod a zero value can be ascertained on the dial indicator.

3 Claims, 2 Drawing Sheets



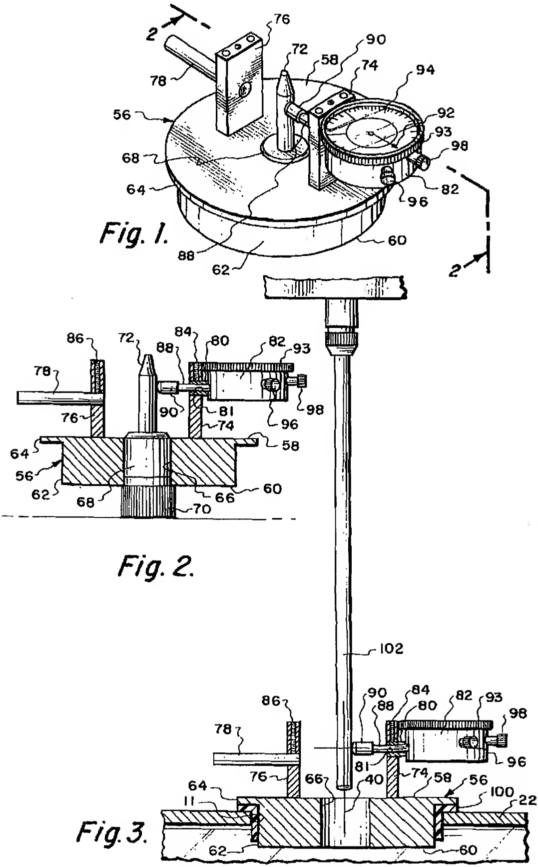


Fig. 1.

Fig. 2.

Fig. 3.

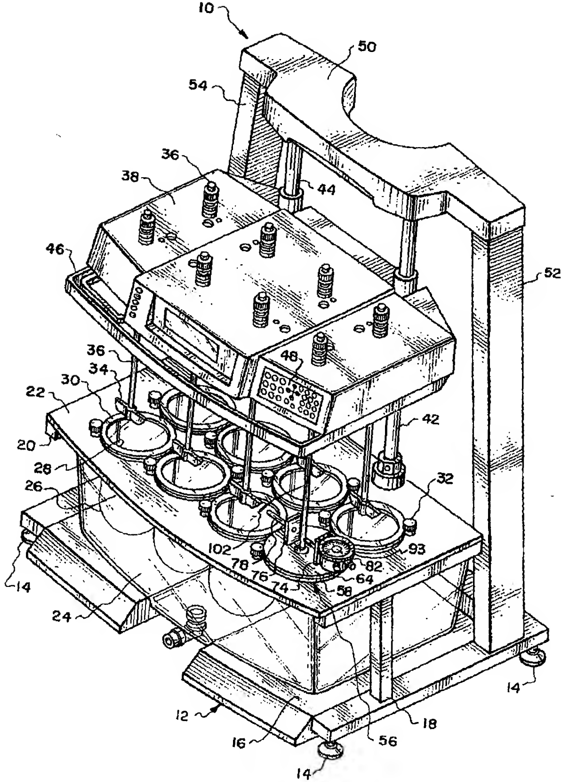

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Fig. 4.

ALIGNMENT VERIFICATION DEVICE FOR A ROTATING SHAFT

BACKGROUND OF THE INVENTION

1) FIELD OF THE INVENTION

The field of this invention relates to a alignment verification device for a rotating shaft, and more particularly to an alignment verification device for a rotating shaft of a dissolution apparatus which uses a rotating shaft to apply a turbulence to a liquid within which is located a pill.

2) DESCRIPTION OF THE PRIOR ART

Drugs are commonly manufactured and sold in pill form. Pills generally refer to tablets, capsules and caplets. Pills are constructed to release drugs into the body over a period of time. It is generally not desirable to release all of the drug immediately into the body. Therefore, it is necessary before a particular drug is marketed to incorporate that drug in pill form and then to ascertain the amount of drug that would be released into the body over a preset period of time.

There are conventionally available pieces of equipment that are used to ascertain the amount of release of a drug into the stomach of a body such as a human body. Generally these pieces of equipment utilize a plurality of flasks each of which contain a quantity of the liquid. Generally the liquid will essentially duplicate the liquid that is commonly contained within the stomach of the body. The most common type of body would be a human body. However, it is certainly within the scope of this invention that the equipment could be utilized to test absorption rates for other bodies such as horses, cows, dogs, cats and other animals.

Into each flask there is deposited a pill of the drug. A mixing device is inserted within each flask and is to be moved in a manner to essentially duplicate the turbulence that generally would be created naturally within the stomach of the body. Aliquots are removed from each flask at preset periods of time with these aliquots to be tested to ascertain the amount of the drug that has been dissolved within each flask. It is common that before a drug is given permission to be sold that a substantial number of such tests are performed with an average being calculated so that the precise dissolving nature of the drug is ascertained.

In order to precisely ascertain the amount of drug that is absorbed, the equipment that is used will subject the flask to a precisely known temperature. Also the mixing device that is placed within each flask must precisely mix the liquid within each flask in exactly the same manner. Therefore, it is important that the mixing device be centrally located within the flask. It is also important that the mixing device not be skewed in any angle but is located in direct alignment with the longitudinal center axis of the flask.

It is common that such testing apparatuses are able to perform a number of such tests simultaneously. Therefore, before such tests are initiated, it is necessary to ascertain that the position of the mixing paddle for each flask is precisely positioned along the longitudinal center axis of its flask. In the past it was common to just "eyeball" the mixing paddle so that the rotating shaft of the mixing paddle would be in substantial alignment with the longitudinal center axis of the flask. However, under current practice, the eyeballing technique is not sufficient.

Additionally, the mixing paddle would be measured by some kind of simple measurement device again to ascertain that the rotating shaft coincides with the longitudinal center axis of the flask. However, at the current time, these simple types of measuring devices are not sufficient to ascertain accurate rates of dissolution of the pill.

There is currently available dissolution testing equipment where a concerted effort is being made so that each test that is performed within each flask is subjected to precisely the same conditions as in each other flask. However, prior to the present invention, there has not been known to Incorporate a device that is designed specifically to calibrate this equipment to insure that each test that is performed within each flask is identically performed.

SUMMARY OF THE INVENTION

The device of this Invention is intended to be used in conjunction with an apparatus that has a plurality of test flasks within which a liquid is to be contained. Generally the liquid will essentially duplicate the acid contained within the stomach of a body such as a human body. Each flask is contained within a bath with this bath being maintained at a preset temperature with the liquid contained in each flask being maintained at this temperature. The stirrer comprises a blade which is mounted on a rotating shaft. The blade is to be movable from a displaced position from the flask to within the flask. There is a separate blade for each flask. The device of the present invention is to be used to precisely ascertain the centering of this blade so that it coincides with the longitudinal center axis of its respective flask. This centering is accomplished by utilizing a calibration adapter assembly that is placed over and completely covering the flask mounting port. Mounted on the calibration adapter assembly is a dial indicator, with the dial indicator having a linearly movable stem. Lineal movement of the stem changes the reading within a measurement reading section of the dial indicator. The free end of the stem is to be placed in contact with the rotating shaft of a paddle. Relative movement is to occur between the shaft and the stem while at the same time observing of the measurement reading section. If there is a significant variance indicating that the shaft is not precisely in alignment with the longitudinal center axis of the flask, the dissolution test apparatus must be repaired to establish correct alignment. Prior to using the dial indicator, generally it would be desirable to insure that the dial indicator is located at a zero starting position. In order to achieve this, a gauge plug that has a protruding rod is mounted within a precisely centrally located through hole mounted within the calibration adapter assembly with the protruding rod being precisely located on the longitudinal center axis of the calibration adapter assembly. Therefore, as the stem is moved about the protruding rod, if the measurement reading section of the dial indicator is not precisely maintained at a zero position, the dial indicator is to be adjusted so that it is located at a zero position.

The primary objective of the present invention is to utilize the rotating shaft centering device of this invention in conjunction with a calibration kit so that a rotating shaft can be checked as to alignment relative to a flask into which the shaft is to be inserted.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an Isometric view of the calibration adapter assembly utilized in conjunction with the alignment verification device for a rotating shaft of the present invention showing the calibration adapter assembly being connected with a gauge plug for purposes of zeroing the position of the dial indicator mounted on the calibration adapter assembly;

FIG. 2 is a cross-sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view similar to FIG. 2 but showing the calibration adapter assembly being mounted in conjunction with the opening which would normally support a flask, the calibration adapter assembly being utilized to ascertain the center position of an alignment shaft which has been substituted for a rotating shaft that is to be inserted within the flask; and

FIG. 4 is an isometric view of an apparatus that is utilized to ascertain the rates of dissolution of pills.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring particularly to the drawings, there is shown in FIG. 4 a dissolution test apparatus 10. The apparatus 10 has a base 12 which is mounted on a plurality of feet 14. The feet 14 are adjustable and it is intended that the feet 14 are to be adjusted so that the upper surface 16 of the base 12 is located precisely level. Mounted on the base 12 are a pair of side mounting members 18 and 20. Placed on the mounting members 18 and 20 is a platform 22. In between the platform 22 and the upper surface 16 there is located a tub 24. Tub 24 rests on the upper surface 16. The tub 24 has an internal chamber which is to be filled with the liquid such as water. The water will be circulated with its temperature being precisely controlled by appropriate circulation and temperature controlling systems which are not shown or described in conjunction with this Invention.

Platform 22 has a series of openings (not shown) with eight in number of such openings being shown. The apparatus 10 could have less openings such as six in number. Mounted in conjunction with each opening is a flask 26. The flask 26 has a mouth 28, Surrounding the mouth 28 is an annular flange 30. Mounted on the platform 22 is a plurality of turnable locking members 32. There are two such locking members 32 for each annular flange 30. Locking members 32 are to be moved to a position to securely fix in position each annular flange 30 thereby securing in position each flask 26 to the platform 22. Disengagement of the locking members 32 for a flask will permit the flask 26 to be removed from the platform 22. The main portion of the flask 26 will be submerged within the water contained within the tub 24 when the flask 26 is supported by the platform 22.

A paddle 34 is to be insertable within each flask 26 with it to be understood that there is a separate paddle 34 for each flask 26. Each paddle 34 is connected to a shaft 36. The shafts 36 are mounted in a head 38, it is to be noted that in referring to FIG. 4 that there are eight in number of the shafts 36. Each shaft 36, and its attached paddle 34, is locatable within a flask 26.

The head 38 is movably mounted on vertical rods 42 and 44. The head 38 is movable on the rods 42 and 44 by manually grasping of the handle 46 and lifting or lowering of the head 38. The paddles 34 can be located in a spaced position above each of their respective flasks 26, as is shown in FIG. 4, or the head 38 can be lowered so that the paddle 34 can be submerged within the liquid contained within its respective flask 26. With the paddles 34 submerged, the rotation of the shafts 36 can be initiated by activating of such through control panel 48. It is to be understood that the speed of rotation of the shafts 36 can be selected according to individual needs. The vertical rods 42 and 44 are mounted between the base 12 and yoke 50. Yoke 50 is also mounted relative to the base 12 by means of support members 52 and 54. The head 38 can be adjusted laterally relative to vertical rods 42 and 44. The position of the head 38 is initially established with the front corner shafts 36 being aligned with the longitudinal center axis 40 of their respective flasks 26. When this position is established; the head 38 is laterally fixed relative to vertical rods 42 and 44.

Referring particularly to FIG. 1, there is shown a calibration adapter assembly 56 which has a flat upper surface 58 and a flat bottom surface 60. The calibration adapter assembly 56 is of circular construction forming a circular sidewall 62. Aligned with the upper surface 58 is an annular flange 64. Centrally formed within the calibration adapter assembly 56 and extending between the upper surface 58 and the bottom surface 60 is a through hole 66.

A gauge plug 68 is to be mounted within the hole 66 in a very close tolerance arrangement. Generally there is not more than a 0.001 inch size differential between the gauge plug 68 and through hole 66. The head 70 of the gauge plug 68 is to abut against the flat bottom surface 60. Fixedly mounted and centrally disposed along the longitudinal center axis of the gauge plug 68 is a protruding rod 72. The position of the protruding rod 72 in conjunction with the gauge plug 68 is precisely located. The protruding rod 72 and the gauge plug 68 are manufactured to a high degree of tolerance. The protruding rod 72 is to be aligned along the longitudinal center axis 40 and extend outward from the flat upper surface 58.

Fixedly mounted on the flat upper surface 58 are blocks 74 and 76. Blocks 74 and 76 are diametrically located opposite each other on opposite sides of the protruding rods 72. Fixedly mounted in the block 76 by means of set screw 86 and extending laterally from block 76 is a rod 78. Rod 78 is to function as a handle that can be used by a human to grasp and rotate the calibration adapter assembly 56. Fixedly mounted within the block 74 by means of set screw 84 is a sleeve 80. The sleeve 80 is fixedly connected to dial indicator housing 82.

Movably retained within the longitudinal through opening 81 of sleeve 80 is a stem 88. The outer end of the stem 88 is formed into a tip 90. Mounted within the dial indicator housing 82 is an appropriate mechanism (not shown) which will move the pointer 92 located on dial face 94. The dial face 94 is to be adjustable so that with the tip 90 coming into contact with protruding rod 72 the pointers 92 should be located at the zero position. The pointer 92 is to be located at the zero position by turning of ring 93 which also turns dial face 94. When the zero position is obtained, lock nut knob 96 is tightened thereby fixing in position the dial face 94 relative to the housing 82. The knob 98 can be manually turned which will result in movement of the stem 88 without the tip 90 being moved against any exterior structure. At times it may be desirable to just move the tip 90 away from rod 72 during initial installation. After installation, the knob 98 is turned until the tip 90 contacts the protruding rod 72 or a shaft 36.

Rod 78 is to be used as a handle to rotate the calibration adapter assembly 56 at least one revolution about the protruding rod 72. At the same time, the user is to observe the dial face 94 and make sure that the pointer 92 remains on the zero position. If the pointer 92 does remain on the zero position, it is assured that the dial indicator housing 82 is precisely concentrically located relative to the longitudinal center axis 40. The gauge plug 68 is thusly referred to as a zeroing mechanism.

The stem 88 is movable linearly in a given direction toward and away from said protruding rod 72 or shaft 36.

The user then retracts the stem 88 by operating of retract knob 98 so as to displace the tip 90 from the longitudinal center axis 40. The gauge plug 68 is then removed from the

through opening 66. A flask 26 is then removed from the annular plastic ring 100 which is mounted within opening 101 of the platform 22. The calibration adapter assembly 56 is then placed within the ring 100 with the annular flange 64 resting against the annular ring 100. This now orients the longitudinal center axis 40 of the calibration adapter assembly 56 in alignment with the longitudinal center axis of the flask 26.

Because of the low frictional characteristics of the annular plastic ring 100, the calibration adapter assembly 56 can be readily rotated manually by the application of a small amount of force to the rod 78. The shaft 36 that aligns with the calibration adapter assembly 56 is removed from the head 38. In its place, there is mounted a precisely manufactured straight alignment shaft 102. The alignment shaft 102 is located against the tip 90. The head 38 is then moved to a lowermost position while observing the position of the pointer 92. Between the lowermost position and the uppermost position of the head 38, the maximum displacement of the pointer 92 of the dial indicator should not exceed 0.50 millimeters. The procedure is to be repeated for each shaft 36.

The alignment shaft 102 is then removed and the shaft 36 reinstalled in position. The head 36 is lowered sufficiently to where tip 90 will contact the shaft 36 at a position directly adjacent its paddle 34. The shaft 36 is then driven so to be rotated at about 50 rpm. The varying of the position of the pointer 92 should not exceed 1.0 millimeter. If that value is exceeded by the pointer 92, the shaft 36 is either straightened or replaced. This procedure is to be repeated for each shaft 36.

What is claimed is:

1. An alignment verification device for a rotating shaft comprising:

a calibration adapter assembly having a longitudinal center axis; and

a dial indicator mounted on said calibration adapter assembly, said dial indicator having a measurement reading section, said dial indicator being movable in a precise circle concentrically about said longitudinal center axis, said dial indicator having a stem which is movable linearly in a given direction, lineal movement of said stem produces different readings within said measurement reading section, said given direction being substantially perpendicular to said longitudinal center axis, whereby said stem is to be placed against an alignment shaft which has been substituted for the rotating shaft with the rotational axis of the alignment shaft coinciding with said longitudinal center axis, and upon rotation of the calibration adapter assembly, any deviation, and the amount thereof, of the alignment shaft (and hence the rotating shaft when it is replaced after removal of the alignment shaft) from said longitudinal center axis will be noted on said measurement reading section.

2. The alignment verification device for a rotating shaft as defined in claim 1 wherein:

handle means mounted on said calibration adapter assembly, said handle means permitting manual pivoting of said calibration adapter assembly about said longitudinal center axis.

3. The alignment verification device for a rotating shaft as defined in claim 1 wherein:

a zeroing mechanism for said calibration adapter assembly to be used prior to connection of said calibration adapter assembly with the rotating shaft, a through hole formed in said calibration adapter assembly, said through hole having a center axis that coincides with said longitudinal center axis, said zeroing mechanism comprising a gauge plug having a protruding rod, said gauge plug located in said through hole in a close tolerance manner with said stem placed against said protruding rod, whereby rotation of said stem is to produce a zero reading on said measurement reading section.

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United States Patent [19]

Ellis

[11] **Patent Number: 6,148,532**

[45] **Date of Patent: Nov. 21, 2000**

[54] **FLATNESS GAGE**

[75] Inventor: **Robert W. Ellis**, Cincinnati, Ohio

[73] Assignee: **General Electric Company**, Cincinnati, Ohio

[21] Appl. No.: **09/182,782**

[22] Filed: **Oct. 30, 1998**

[51] **Int. Cl.**^{7} **G01B 3/22**; G01B 5/00

[52] **U.S. Cl.** **33/533**; 33/549

[58] **Field of Search** 33/533, 549, 551, 33/553, 554, 555, 556, 559, 832, 833

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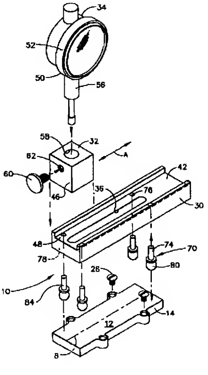
Primary Examiner—Diego Gutierrez
Assistant Examiner—Faye Francis
Attorney, Agent, or Firm—Andrew C. Hess; Gerry S. Gressel

[57] **ABSTRACT**

An apparatus for measuring flatness of a surface includes a locator element slidingly engageable with a slider element in a first direction, and a height measuring instrument having a linear probing device is mounted to the slider element. An alignment feature is used for limiting relative motion between the sliding element and the locator element to the first direction when the slider element is engaged with the locator element. An exemplary embodiment includes a locator block having a top side and a bottom side and a slider block engageable with the locator block on the top side. An elongated aperture is disposed through the locator block and is elongated in the first direction. A mechanical dial indicator with a plunger rod projecting is mounted in the slider block and the plunger rod is positionable through the elongated aperture. A recessed slideway is disposed in the top side of the locator block and the slider block has a squared off end conforming to shape of the recessed slideway to limit relative motion between the blocks to the first direction.

14 Claims, 5 Drawing Sheets



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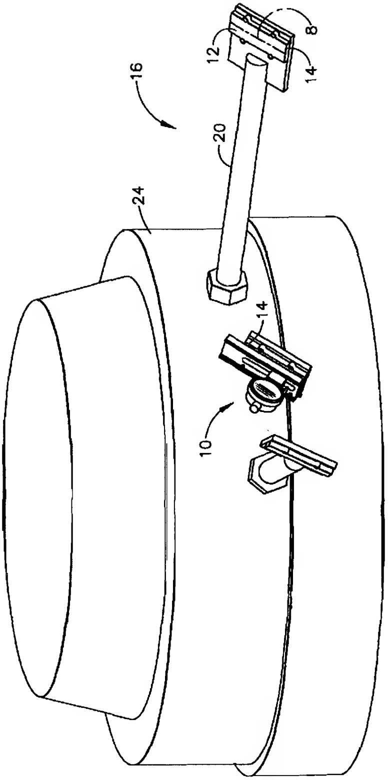

FIG. 1

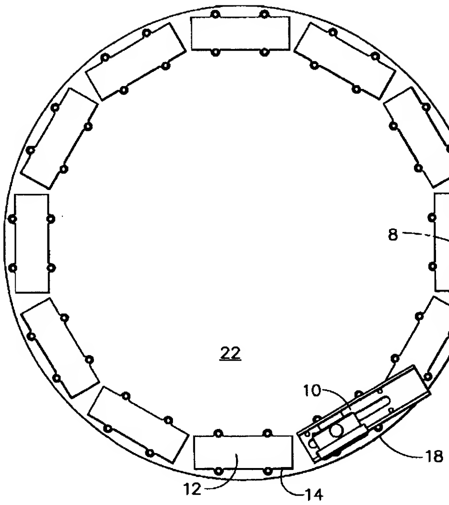

FIG. 2

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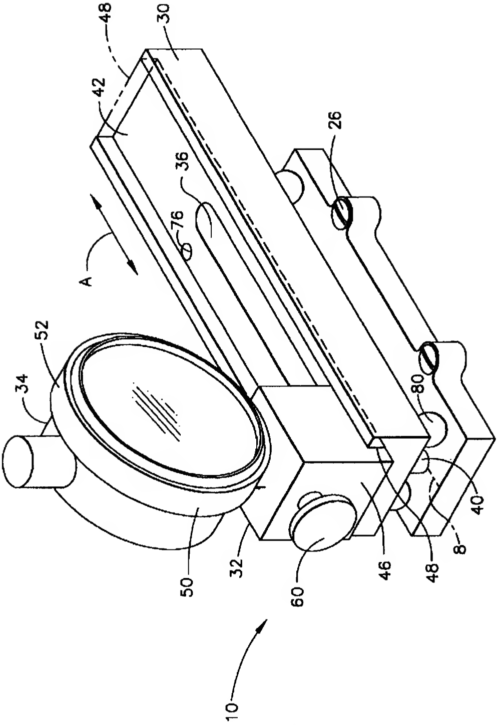

FIG. 3

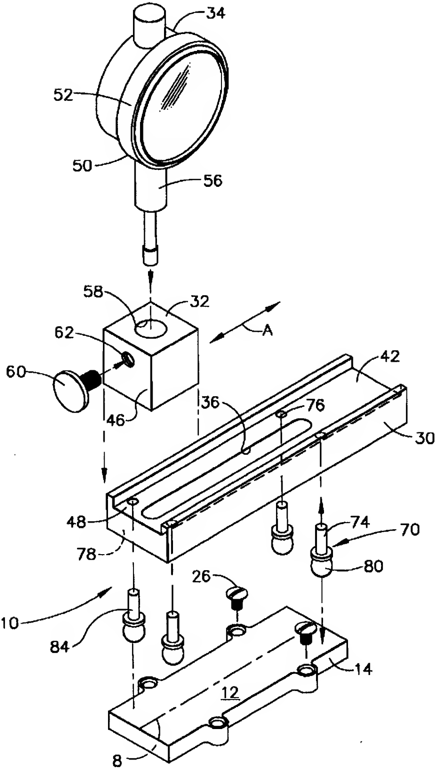

FIG. 4

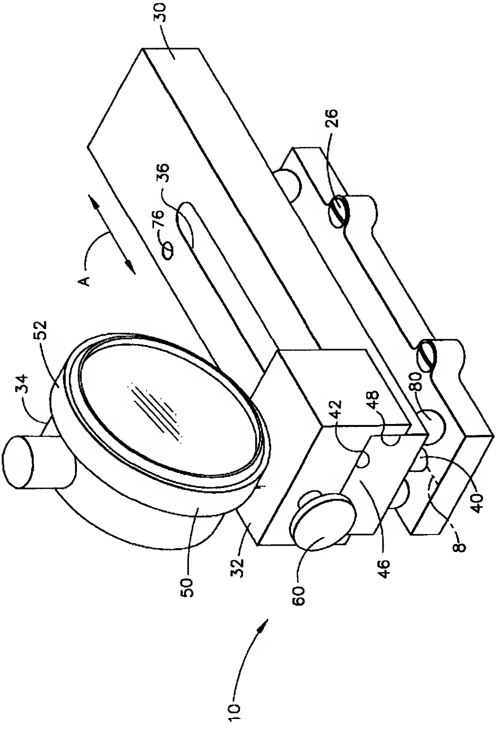

FIG. 5

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FLATNESS GAGE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to flatness gages and dial indicators and, more particularly, to handheld flatness gages incorporating height measuring devices such as dial indicators, particularly as used in conjunction with Almen strip holders.

2. Discussion of the Background Art

Almen strips have long been used for quality control of shot peening processes. Flat holders are used to hold the Almen strips in shot peening cells to test the effectiveness and quality of the shot peening procedure and apparatus. Almen strips are well known for use in the field of shot peening quality control, see U.S. Pat. No. 2,620,838. The Almen strips are held in Almen strip holders and shot peened in the cells. The effectiveness of the Almen strip test and its usefulness as a quality assurance procedure is very much dependant on the repeatability of the Almen strip testing procedure. There is a need to assure the flatness of a flat surface of the Almen strip holder against which the Almen strip is held during the shot peening of the Almen strip. This is not always an easy thing to do, particularly, when the Almen strip holder is mounted on a model designed to simulate the part being shot peened. Models of gas turbine engine parts such as rotor disks and blades are often built with Almen strip holders mounted at key positions to simulate the shot peening process for quality control purposes. Almen strip holder flat surfaces should be flat and in one example it should be within 0.001 inches so that the Almen intensity values are not corrupted. Holders with flat surfaces that are slightly concave or convex can reduce or increase curvature of the peened strip and produce intensity values that are too low or too high. Simple fixtures with accessible Almen strip holders can be easily checked for flatness on a surface plate but Almen strip holders that are attached or welded to scrap parts or test models are difficult, if not impossible, to check. Therefore, it is very desirable to have a handheld device that is portable and capable of checking flatness of Almen strip holders in hard to reach or otherwise inaccessible locations. It is desirable to have an easy to use flatness measuring device that allows for a quick check of the flatness of the Almen strip holder. It is also desirable that the device be portable, handheld and operated, and easily maneuverable in order to be used on model positions that are difficult to access.

SUMMARY OF THE INVENTION

Briefly, in accordance with one aspect of the present invention, an apparatus for measuring flatness of a surface includes a locator element slidingly engageable with a slider element in a first direction, and a height measuring instrument having a linear probing device mounted to the slider element. An alignment feature is used for limiting relative motion between the sliding element and the locator element to the first direction when the slider element is engaged with the locator element.

In the preferred embodiment, the locator element is a locator block having a top side and a bottom side and the slider element is a slider block engageable with the locator block on the top side. An elongated aperture is disposed through the locator block and is elongated in the first direction. The linear probing apparatus is positionable through the elongated aperture. The alignment feature is a recessed slideway in one of the blocks adapted for receiving the other one of the blocks which has a squared off end conforming to a rectangular shape of the recessed slideway to limit relative motion between the blocks to the first direction. The recessed slideway is preferably in the top side of the locator block. The height measuring instrument may be a mechanical dial indicator with a plunger rod projecting therefrom which is the linear probing device. Other height measuring instruments may include digital height measuring instruments and devices. The dial indicator preferably includes a frame having a dial portion and a tube portion extending outward therefrom and circumscribing the plunger rod. The frame may be mounted to the slider block by the tube portion disposed in a holding aperture through the slider block. Standoff feet may be placed on the bottom side of the locator block and may be studs extending out from the bottom side of the locator blocks and may have tooling balls on bottom ends of the studs.

One particular embodiment of the present invention is an apparatus for measuring flatness of a Almen strip holding surface of an Almen strip holder. A centering feature is used for centering the probing means substantially along a longitudinal centerline of the Almen strip holding surface. The centering feature may be the elongated aperture generally centered along and disposed through the locator block and elongated in the longitudinal direction.

In the drawings as hereinafter described, a preferred embodiment is depicted; however, various other modifications and alternate constructions can be made thereto without departing from the true spirit and scope of the invention.

ADVANTAGES OF THE INVENTION

The present invention is effective in measuring the flatness of the flat holding surface of Almen strip holders and is useful in a quality assurance procedure is very much dependant on the repeatability of the Almen strip testing procedure. It is relatively small, portable, handheld, and easy to use by a shot peening machine operator during production and/or calibration of the shot peening machine. It can be used to assure the flatness of the flat surface of the Almen strip holder that is mounted on a model designed to simulate the part being shot peened and particularly ones that are difficult to access.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the present invention are set forth and differentiated in the claims. The invention, together with further objects and advantages thereof, is more particularly described in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view of an apparatus for measuring flatness of Almen strip holders mounted on a shot peening model in accordance with an exemplary embodiment of the present invention;

FIG. 2 is an elevated view of the apparatus for measuring flatness of Almen strip holders mounted on an alternative shot peening model;

FIG. 3 is an enlarged view of the apparatus for measuring flatness diffuser over an Almen strip holder illustrated in FIGS. 1 and 2;

FIG. 4 is an exploded view of the apparatus illustrated in FIG. 3; and

FIG. 5 is an elevated view of an alternate embodiment of the apparatus in FIG. 3.

DETAILED DESCRIPTION

Illustrated in FIG. 1 is an exemplary embodiment of an apparatus 10 used for measuring flatness of a surface such as

an Almen strip holding flat surface 12 having a longitudinally extending centerline 8 on an Almen strip holder 14. Almen strip holders 14 are used on shot peening models for quality assurance of shot peening processes, machines, and cells. A rotor and blade model 16 is illustrated in FIG. 1 while a rotor disk model 18 is illustrated in FIG. 2. The Almen strip holders 14 are mounted on mounting rods 20 extending radially from a conical body 24 which models a rotor section of a gas turbine engine. The Almen strip holders 14 are portioned to represent the areas for quality assurance testing of the rotor parts they represent. In FIG. 2 the Almen strip holders 14 are portioned to represent positions on blades of a rotor that shot peened. The Almen strip holders 14 are mounted directly to a circular surface 22 of the disk model 18 in FIG. 2.

Illustrated in FIGS. 3 and 4 is the Almen strip holder 14 and the flat surface 12 upon which an Almen strip (not shown) is placed and secured by hold down screws 26. The apparatus 10 is used to measure the flatness of the flat surface 12 by measuring variances in the height of the surface. A locator block 30 is placed over the flat surface 12 and a slider block 32 is slideably engaged with the locator block. A dial indicator 34 exemplifies one type of height measuring means that can be attached to the slider block 32 to make flatness or height measurements on the flat surface 12. A longitudinally elongated aperture 36 is disposed through the locator block 30 and a plunger rod 40, an exemplary linear probing means, is positionable through the elongated aperture to engage the flat surface 12. The dial indicator 34 has a frame 50 with a dial portion 52 and a tube portion 56 extending outward therefrom and circumscribed about said rod 40. The frame 50 is mounted to the slider block 32 by the tube portion 56 disposed in a holding aperture 58 through the slider block and removably secured in place by set screw 60 in a threaded aperture 62 through the slider block 32 which interacts the holding aperture 58.

Alignment of the plunger rod 40 with the longitudinally extending centerline 8 is provided by a recessed slideway 42 in the locator block 30 for receiving the slider block 32. The slider block 32 has a squared off end 46 conforming to a rectangular shape 48 of the recessed slideway 42 to limit relative motion between the blocks back and forth in a first longitudinal direction indicated by arrow A.

Standoff feet 70 on a bottom side 78 of the locator block 30 facilitates the handheld application and positioning of the locator block on the flat surface 12. The standoff feet 70 are illustrated as threaded studs 74 extending out from threaded apertures 76 on a bottom side 78 of the locator block 30 and tooling balls 80 may be used on bottom ends 84 of the studs. This configuration helps prevent and minimizes scuffing and scratching of the flat surface 12.

Illustrated in FIG. 5 is an alternative embodiment with the recessed slideway 42 in the slider block 32 for receiving the locator block 30. The locator block 30 has the squared off end 46 conforming to the rectangular shape 48 of the recessed slideway 42 in the slider block 32 to limit relative motion between the blocks back and forth in the first longitudinal direction indicated by the arrow A.

While the preferred embodiment of our invention has been described fully in order to explain its principles, it is understood that various modifications or alterations may be made to the preferred embodiment without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. An apparatus for measuring flatness of a surface comprising:

a locator means slidingly engageable with a slider means in a first direction,

a height measuring means with a linear probing means, said height measuring means mounted to said slider means,

an alignment means for limiting relative motion between said sliding means and said locator means to said first direction when said slider means is engaged with said locator means,

an elongated aperture disposed through said locator means,

said elongated aperture elongated in said first direction, and

said linear probing means is positionable through said elongated aperture.

2. An apparatus for measuring flatness of a surface comprising:

a locator block slidingly engageable with a slider block in a first direction,

a height measuring means with a linear probing means, said height measuring means mounted to said slider means,

an alignment means for limiting relative motion between said sliding means and said locator means to said first direction when said slider means is engaged with said locator means,

said locator block having a top side and a bottom side wherein said slider block is engageable with said locator block on said top side,

an elongated aperture is disposed through said locator block,

said elongated aperture elongated in said first direction, and

said linear probing means is positionable through said elongated aperture.

3. An apparatus as claimed in claim 2 wherein said alignment means comprises a recessed slideway in one of said blocks for receiving the other one of said blocks and said other one of said blocks has a squared off end conforming to shape of said recessed slideway to limit relative motion between said blocks to said first direction.

4. An apparatus as claimed in claim 3 wherein said height measuring means comprises a dial indicator and said linear probing means comprises a plunger rod projecting therefrom.

5. An apparatus as claimed in claim 4 wherein said dial indicator includes a frame having a dial portion and a tube portion extending outward therefrom and circumscribing said plunger rod, and said frame is mounted to said slider block by said tube portion disposed in a holding aperture through said slider block.

6. An apparatus as claimed in claim 5 further comprising standoff feet on said bottom side of said locator block.

7. An apparatus as claimed in claim 6 wherein said standoff feet comprise studs extending out from said bottom side and tooling balls on bottom ends of said studs.

8. An apparatus for measuring flatness of an Almen strip holding surface of an Almen strip holder, said apparatus comprising:

a locator means slidingly engageable with a slider means in a longitudinal direction,

a height measuring means with a linear probing means, said height measuring means mounted to said slider means,

a centering means for centering said probing means substantially along a longitudinal centerline of the

Almen strip holding surface extending in said longitudinal direction,

said centering means including an elongated aperture generally centered along and disposed through said locator means,

said linear probing means is positionable through said elongated aperture, and

an alignment means for limiting relative motion between said sliding means and said locator means to said longitudinal direction when said slider means is engaged with said locator means.

9. An apparatus for measuring flatness of a Almen strip holding surface of an Almen strip holder, said apparatus comprising:

a locator block slidingly engageable with a slider block in a longitudinal direction,

a height measuring means with a linear probing means, said height measuring means mounted to said slider means,

a centering means for centering said probing means substantially along a longitudinal centerline of the Almen strip holding surface extending in said longitudinal direction,

an alignment means for limiting relative motion between said sliding means and said locator means to said longitudinal direction when said slider means is engaged with said locator means,

said locator block having a top side and a bottom side wherein said slider block is engageable with said locator block on said top side,

said centering means comprises an elongated aperture generally centered along and disposed through said locator block,

said elongated aperture elongated in said longitudinal direction, and

said linear probing means is positionable through said elongated aperture.

10. An apparatus as claimed in claim 9 wherein said alignment means comprises a recessed slideway in one of said blocks for receiving the other one of said blocks and said other one of said blocks has a squared off end conforming to shape of said recessed slideway to limit relative motion between said blocks to said longitudinal direction.

11. An apparatus as claimed in claim 10 wherein said height measuring means comprises a dial indicator and said linear probing means comprises a plunger rod projecting therefrom.

12. An apparatus as claimed in claim 11 wherein said dial indicator includes a frame having a dial portion and a tube portion extending outward therefrom and circumscribing said plunger rod and said frame is mounted to said slider block by said tube portion disposed in a holding aperture through said slider block.

13. An apparatus as claimed in claim 12 further comprising standoff feet on said bottom side of said locator block.

14. An apparatus as claimed in claim 13 wherein said standoff feet comprise studs extending out from said bottom side and tooling balls on bottom ends of said studs.

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Walters

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(45) **Date of Patent:** **Feb. 13, 2001**

(54) **SEMICONDUCTOR WAFER FIXTURE FOR ALIGNMENT IN A GRATING EXPOSURE PROCESS**

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(*) Notice: Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

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(22) Filed: **Mar. 25, 1999**

(51) **Int. Cl.**^{7} **G01D 21/00**; B65G 49/07; G01B 1/00

(52) **U.S. Cl.** **33/533**; 33/613; 33/645; 33/549; 414/935; 414/936; 414/941

(58) **Field of Search** .... 33/533, 549, 613, 33/645, DIG. 2; 414/935, 936, 941

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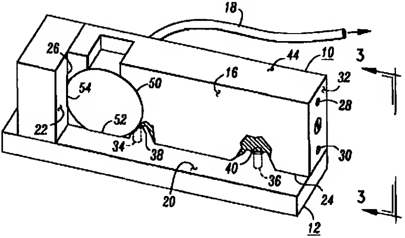
(74) *Attorney, Agent, or Firm*—Wendy W. Koba

(57) **ABSTRACT**

A fixture and method for providing accurate and repeatable alignment and attachment of a semiconductor wafer to a corner cube exposure fixture includes a vacuum-assisted wafer holder of rectangular shape. The wafer holder is first placed upon an L-shaped loading fixture so that a wafer may be positioned against the front surface of the holder and manipulated until the pair of wafer flats abut each leg of the L-shaped fixture. When so aligned, a vacuum is applied to secure the attachment and alignment of the wafer vis-à-vis the wafer holder. The wafer holder is thereafter inserted in a corner cube exposure fixture, where the fixture is formed to include a right-angle bracket with alignment features formed in one leg of the angle. The wafer holder also includes alignment features in its bottom surface, where these features are formed to mate with the bracket upon attachment. The proper placement and alignment of the wafer holder to the exposure fixture results in the wafer being disposed immediately adjacent to the reflective surface used to form the interference pattern on the wafer surface. The right angle in the fixture ensures that the mirror surface remains orthogonal to the wafer surface such that a uniform grating may be formed across the wafer surface.

14 Claims, 5 Drawing Sheets



S049

FIG. 1

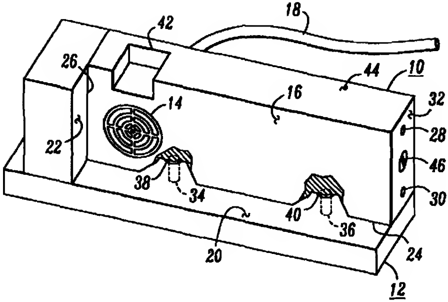
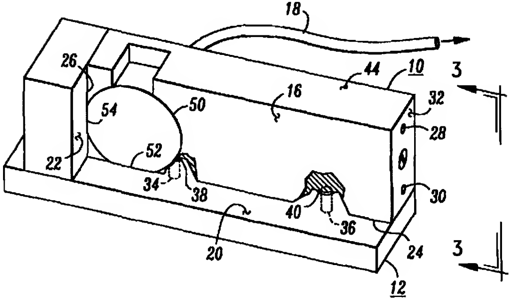


FIG. 2



SoSo

FIG. 3

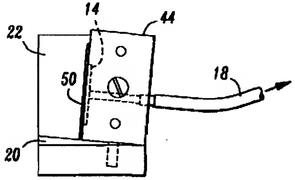
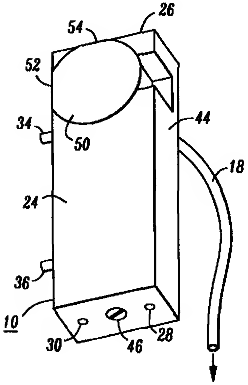
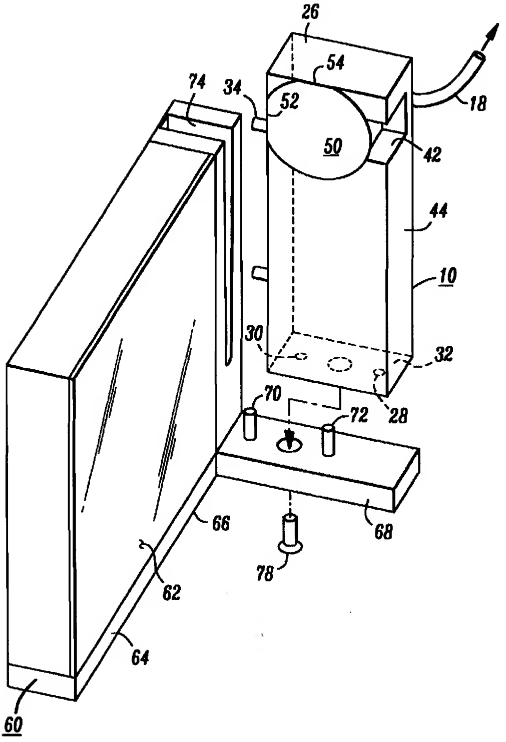


FIG. 4



Sa51

FIG. 5



S052

FIG. 6

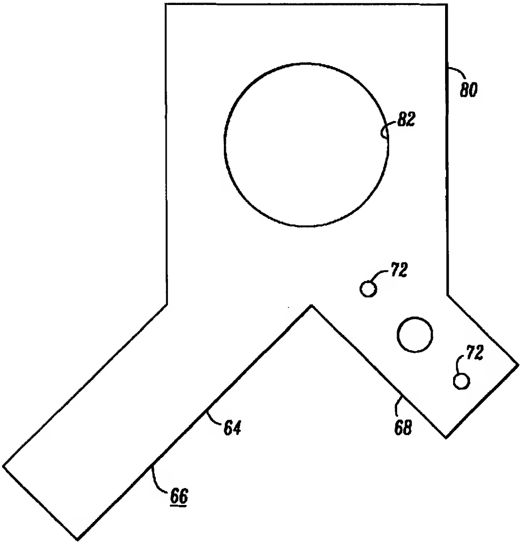
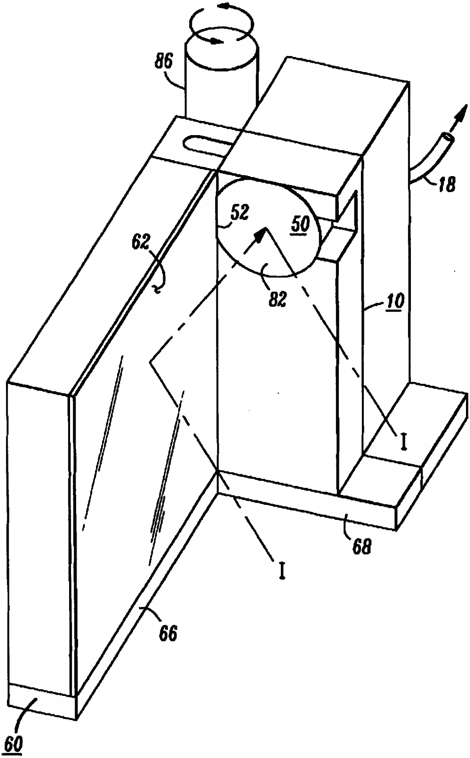


FIG. 7



SEMICONDUCTOR WAFER FIXTURE FOR ALIGNMENT IN A GRATING EXPOSURE PROCESS

TECHNICAL FIELD

The present invention relates to a semiconductor wafer fixture a method for providing alignment of a wafer during a grating exposure process and, more particularly, to a vacuum-controlled fixture and method for providing accurate and repeatable alignment of a semiconductor wafer to a reflective surface for holographic grating exposure.

BACKGROUND OF THE INVENTION

Periodically corrugated surfaces (gratings) are widely used in many different optoelectronic devices. For example, a surface grating structure can be used to provide a feedback path for distributed feedback (DFB) and distributed Bragg reflector (DBR) lasers. As an input-output coupler for selectively exciting the modes of an optical waveguide, gratings have advantages over other coupling techniques in being an integral part of the waveguide, mechanically simple, and capable of coupling into waveguides fabricated from high index materials. Additional applications include integrated narrowband filters, light deflectors, and phase matching elements.

A conventional method of forming the grating structure is referred to as a "holographic" method, in which a grating relief pattern is produced by interferometric exposure and development of photoresist on the wafer surface. The grating is then transferred to the substrate by ion-beam milling or chemical etching. Various techniques exist to generate the required interference pattern, including splitting a signal into two beams (spatially), then redirecting the two beams to the wafer surface to form the desired interference pattern. In an alternative arrangement, referred to herein as a "corner cube", the original exposure beam is directed at a mirror surface disposed at 90° with respect to the wafer. The reflections from the mirror, in combination with the beam directly impinging the wafer, will form an interference pattern on the wafer, where the angle of incidence of the exposure beam on the mirror will determine the periodicity of the grating formed on the wafer.

In many situations it is necessary to control the grating structure and periodicity as carefully as possible. For example, current DFB lasers utilize a grating a structure with dimensions on the order of 0.1 μm lines and spaces. Small angular errors when manufacturing the grating by UV exposure can have drastic effects on the performance and manufacturing of the DFB lasers. In the "corner cube" exposure arrangement, such angular errors have been attributed to misalignment of the wafer with the reflective surface, thus varying the grating exposed on the wafer surface. In particular, a misalignment may result in the grating varying in periodicity across the surface of the wafer. The repeatability of the wafer-to-mirror alignment is also problematic, resulting in the gratings being slightly different on each wafer as a number of wafers are processed in succession.

SUMMARY OF THE INVENTION

The limitations with the corner cube exposure fixture are addressed by the present invention, which relates to a semiconductor wafer fixture and method for providing alignment of a wafer during a grating exposure process and, more particularly, to a vacuum-controlled fixture and method for providing accurate and repeatable alignment of a semiconductor wafer to a reflective surface for holographic grating exposure.

In accordance with the present invention, a semiconductor wafer is positioned against a vacuum opening in a wafer holder, where the holder is removably attached to a loading fixture. The holder and loading fixture are attached such that a loaded wafer's major and minor flats are butted against flat surfaces of the loading fixture. The wafer may be adjusted until its flats are in intimate contact with these adjacent surfaces of the loading fixture. Once the wafer is in place, a vacuum is applied to draw the wafer against the holder. The holder is then removed from the loading fixture, and attached to a corner cube exposure fixture, where the holder is positioned at an angle of 90° with respect to a mirror surface of the corner cube exposure fixture. The application of the vacuum to the holder results in maintaining the desired position of the wafer with respect to the holder; that is, the major and minor flats of the wafer are coincident with the respective edges of the holder. The portion of the corner cube exposure fixture beyond the mirror surface is formed to include alignment features that mate with like alignment features formed on the wafer holder. When the holder is therefore attached to and aligned with the mirror surface, the wafer flat will automatically align with the mirror surface. The self-aligned nature of the arrangement of the present invention thus results in the ability to expose uniform grating structures across the surface of the wafer, as well as expose gratings of the same periodicity on each subsequent wafer being processed.

In a preferred embodiment of the present invention, the alignment features comprise a mating set of pins and apertures, where a same set of alignment features may be used to attach the holder to the loading fixture as well as to align the holder to the corner cube exposure fixture. A second set of alignment features may be formed on an orthogonal surface of the holder and mated with similar features on the corner cube exposure fixture to ensure accurate alignment.

In an alternative embodiment, the holder may be further formed to include a screw-down attachment for further securing the wafer holder to the corner cube exposure fixture. This additional attachment of the holder to the exposure fixture further prevents relative movement of the holder with respect to the exposure fixture which may occur, for example, as the fixture is rotated to change the exposure beam's angle of incidence.

Other and further features and embodiments of the present invention will become apparent during the course of the following discussion and by reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings,

FIG. 1 contains an illustration of an exemplary wafer holder in position with an exemplary loading fixture, showing in particular the vacuum opening on the holder for securing a wafer to the holder;

FIG. 2 is a view of the arrangement of FIG. 1, with a semiconductor secured, via the vacuum opening to the holder, and aligned with the respective surfaces of the loading fixture;

FIG. 3 is a side view the arrangement of FIG. 2, taken along line 3—3, showing in particular the tilt of the holder with respect to the fixture so as to aid in the securing of the wafer to the holder;

FIG. 4 is a view of a free-standing wafer holder, subsequent to its removal from the loading fixture and prior to its attachment to a corner cube exposure fixture;

FIG. 5 illustrates the attachment of the wafer holder of FIG. 4 to an exemplary corner cube exposure fixture, the arrows indicating the direction of attachment;

FIG. 6 is a bottom view of an exemplary corner cube exposure fixture; and

FIG. 7 contains an illustration of an exemplary vacuum-assisted wafer holder attached to and aligned with an exemplary corner cube exposure fixture, the illustration including a central mounted spindle for modifying the angular location of the arrangement with respect to an incident exposure beam, the arrows above the spindle indicating the direction of movement of the arrangement.

DETAILED DESCRIPTION

An exemplary vacuum-assisted rectangular wafer holder 10, formed in accordance with the present invention, is shown in FIG. 1 as (removably) attached to an exemplary loading fixture 12. Rectangular holder 10 is formed to include a vacuum opening 14 in a front surface 16, where vacuum opening 14 is coupled to a vacuum source (not shown), via a vacuum connection 18 attached to holder 10. Loading fixture 12 is generally formed as an "L-shaped" fixture including a lower surface 20 and a side surface 22, with side surface 22 formed as perpendicular to lower surface 20. Rectangular holder 10 is positioned with respect to loading fixture 12 such that a first side surface 24 of holder 10 rests against lower surface 20 of fixture 12 and a top surface 26 of holder 10 rests against side surface 22 of fixture 12. As will be discussed below in association with FIG. 2, this positioning of rectangular wafer holder 10 with respect to fixture 12 allows for a semiconductor wafer (not shown) to be repeatably aligned with holder 10.

Referring back to FIG. 1, holder 10 is shown as also including a set of alignment features, where these features will be used hereinafter when holder 10 is attached to an exemplary corner cube exposure fixture (as discussed below in association with FIGS. 5 and 6). In particular, rectangular wafer holder 10 includes a first set of alignment features 28, 30 formed in a bottom surface 32 of holder 10, where in this particular embodiment alignment features 28,30 comprise a pair of apertures. A second set of alignment features 34,36 are formed in side surface 24 and mate with a set of alignment features 38,40 formed in lower surface 20 of loading fixture 12. In the embodiment illustrated in FIG. 1, second set of alignment features 34,36 are shown as pins that mate with alignment apertures 38,40 of fixture 12. Holder 10 may also include a detent 42, formed in a side surface 44, to aid in the placement and adjustment of a semiconductor wafer against front surface 16 of holder 10. A threaded attachment member 46 (optional) is illustrated as formed in bottom surface 32 of holder 10 and may be used, as discussed below, to secure the attachment of holder 10 to a corner cube exposure fixture.

FIG. 2 illustrates the apparatus as described above in association with FIG. 1, with a semiconductor wafer 50 disposed against front surface 16 of holder 10. In accordance with the present invention, wafer 50 is positioned such that its major flat 52 rests against lower surface 20 of loading fixture 12 and its minor flat 54 abuts side surface 22 of loading fixture 12. The inclusion of detent 42 in holder 10 allows for wafer 50 to be manipulated (by using a pair of tweezers, for example) until both flats 52 and 54 are accurately positioned. Once positioned, therefore, wafer flats 52,54 will be similarly aligned with the associated edges of holder 10. After wafer 50 has been manipulated into place, a vacuum may be turned on so that vacuum opening 14 (underneath wafer 50) will pull wafer 50 against front surface 16 of holder 10, securing wafer 50 in place.

In accordance with the teachings of the present invention, the utilization of surfaces 20,22 of loading fixture 12 as alignment surfaces ensures that each wafer subsequently attached to holder 10 will always align with the edges of holder 10, resulting (as discussed below) in repeatable accuracy of the following grating exposure.

In a preferred embodiment of the present invention, lower surface 20 of loading fixture 12 is angled downward from front to back so that wafer 50 will naturally rest against front surface 16 of holder 10 prior to the application of a vacuum. FIG. 3 contains a cut-away side view of the arrangement of FIG. 2, illustrating in particular the front-to-back tilt of lower surface 20.

Once wafer 50 has been properly aligned against surfaces 20,22 of loading fixture 12 (and the vacuum applied to secure wafer 50 in place), holder 10 is removed from loading fixture 12. FIG. 4 illustrates holder 10 upon removal from loading fixture 12. Particularly evident in this view is the alignment of major flat 52 of wafer 50 with side surface 24 of holder 10. As will be discussed below, this alignment is critical to obtaining accurate alignment of wafer 50 with the reflective surface used to form the holographic grating pattern on the wafer surface. During the process of removing holder 10 from loading fixture 12 and thereafter attaching holder 10 to a corner cube exposure fixture, a vacuum force is maintained to ensure that wafer 50 remains securely attached to holder 10.

FIG. 5 illustrates the process of attaching holder 10 to an exemplary corner cube exposure fixture 60. As shown, exposure fixture 60 includes a mirror surface 62 formed on a first leg 64 of a right-angle fixture 66. The remaining leg 68 of right-angle fixture 66 is formed to include a set of alignment features 70,72 that mate with alignment features 30 and 28, respectively, of holder 10 upon attachment (as indicated by the arrows in FIG. 5). First leg 64 of fixture 66 further includes a channel portion 74 disposed next to mirror surface 62. As shown, when holder 10 is being attached to exposure fixture 60, alignment features 34,36 of holder 10 will be inserted into channel portion 74, sliding down along channel 74 as bottom surface 32 of holder 10 comes into contact with second leg 68 of right-angle fixture 66. Second leg 68 may be formed to include a threaded aperture 76 that aligns with (optional) threaded aperture 46 of holder 10. A threaded screw 78 is then inserted through the underside of second leg 68 to affix holder 10 to second leg 68. As discussed above, this additional screw attachment is considered to be optional, further ensuring that holder 10 remains in position with respect to exposure fixture 60.

In the utilization of a corner cube exposure fixture to expose gratings of different periodicity on a wafer surface, it is desirable to modify the position of the fixture with respect to the exposure light source so as to change the angle of incidence of the exposure beam on the mirror surface. In a preferred embodiment, corner cube exposure fixture is rotated with respect to a fixed light source to modify the angle of incidence. In this arrangement, corner cube exposure fixture 60 is mounted on a central spindle and rotated about a central axis formed by the coincidence of wafer holder 10 and exposure fixture 60. FIG. 6 contains a bottom view of right-angle fixture 66, formed to include a rear portion 80 with a rear aperture 82. In operation, as shown in FIG. 7, a spindle 86 is inserted over aperture 82 and used to rotate the final structure to change the angle of incidence of an exposure beam I is also shown in this illustration.

In accordance with the present invention, the location of wafer **50** with respect to holder **10** results in flat **52** of wafer **50** being positioned directly against, and at an angle of 90° to, mirror surface **62**. Advantageously, the positioning of wafer **50** with respect to mirror surface **62** can be controlled such that the center line of wafer **50** will coincide with the center line of mirror surface **62**. Thus, any possible perturbations in the exposed grating due to mirror "edge effects" are essentially eliminated by using the central, more planar area of the mirror to provide the necessary reflections to form the grating interference pattern. Additionally, the alignment arrangement of the present invention is repeatable from wafer to wafer, as each wafer is accurately positioned using loading fixture **12**, as discussed above. Since each wafer is in essentially identical alignment, the gratings exposed by the interference of reflected beam I with that portion of incident beam I directly impinging wafer **50** will result in essentially identical gratings (denoted by lines **82**) being exposed on each wafer so processed. Advantageously, the use of a vacuum to hold wafer **50** against holder **10** with a uniform force across the wafer surface results in an essentially uniform spacing of the gratings across the surface of the wafer.

It is to be understood that there exist various modifications to the above-described arrangement that are considered to fall within the spirit and scope of the present invention. For example, the alignment features may comprise more than a single pair of alignment features, and the use of pins and apertures may be reversed. Additionally, vacuum port **18** may be disposed at locations other that the back surface of holder **10**. These and other modifications are all considered to be within the scope of the present invention as defined by the claims appended hereto.

What is claimed is:

1. An arrangement for mounting and aligning a semiconductor wafer with a corner cube exposure fixture, the corner cube exposure fixture including a mirror surface for use in forming holographic grating patterns on a semiconductor wafer surface, the arrangement comprising

a rectangular wafer holder including a vacuum aperture through a front surface thereof for securing a semiconductor wafer thereto, said holder further comprising a plurality of alignment features formed in a bottom surface and a side surface thereof, said vacuum aperture disposed such that upon attachment of a wafer to said wafer holder, the wafer flats will be adjacent to a top surface and said side surface of said wafer holder; and

an L-shaped loading fixture defined as including a lower surface and a perpendicular side surface, said loading fixture having suitable dimensions with respect to said rectangular wafer holder such that said wafer holder side surface rests against said loading fixture lower surface and said wafer holder top surface rests against said loading fixture side surface, wherein upon placement of a wafer against said wafer holder top surface, a first flat surface of said wafer abuts said loading fixture lower surface and a second flat surface of said wafer abuts said loading fixture side surface.

2. An arrangement as defined in claim **1** wherein the arrangement further comprises

a corner cube exposure arrangement comprising a right-angle fixture defined by a first leg and a second leg, said fixture including a mirror surface formed on the first leg and a plurality of alignment features formed on the second leg of said right-angle fixture, said plurality of alignment features for mating with the alignment features formed on the bottom surface of the wafer holder upon mating of said wafer holder with said corner cube exposure arrangement, said corner cube exposure arrangement further comprising an alignment channel disposed adjacent to said mirror surface for communicating with the plurality of alignment features formed on the side surface of said wafer holder upon mating of said wafer holder with said corner cube exposure arrangement.

3. An arrangement as defined in claim **2** wherein the wafer holder further comprises a threaded aperture included in the bottom surface thereof and the right-angle fixture second leg comprises a threaded aperture for aligning with said wafer holder threaded aperture, said arrangement further comprising a screw member for engaging both threaded apertures and attaching said wafer holder to said right-angle fixture.

4. An arrangement as defined in claim **1** wherein the wafer holder further comprises a detent formed in a side surface to assist in the manipulation of a semiconductor wafer with respect to said holder.

5. An arrangement as defined in claim **1** wherein the loading fixture lower surface is angled so as to tilt downward from front to back, said tilt for assisting in the placement of a wafer against the wafer holder front surface.

6. An arrangement as defined in claim **1** wherein the wafer holder includes a vacuum port disposed through a rear surface thereof, said vacuum port in contact with the vacuum aperture on the front surface thereof such that upon the application of a vacuum force, a semiconductor wafer disposed over said vacuum aperture will remain attached to said wafer holder front surface.

7. An arrangement as defined in claim **2** wherein the wafer holder bottom surface alignment features comprise a plurality of apertures and the corner cube exposure fixture plurality of alignment features comprise a plurality of pins such that said pins mate with said apertures upon attachment of said wafer holder to said corner cube exposure fixture.

8. An arrangement as defined in claim **7** wherein the plurality of wafer holder bottom surface alignment apertures comprise a pair of alignment apertures and the corner cube exposure fixture plurality of alignment features comprise a pair of alignment pins.

9. An arrangement as defined in claim **2** wherein the wafer holder side surface alignment features comprise a plurality of alignment pins for engagement with the corner cube exposure fixture alignment channel.

10. An arrangement as defined in claim **9** wherein the plurality of alignment pins comprises a pair of alignment pins.

11. A method of aligning a semiconductor to a corner cube exposure fixture for use in a holographic grating exposure process, the method comprising the steps of:

a) providing a rectangular wafer holder including a vacuum aperture through a front surface thereof, said holder further comprising a plurality of alignment features formed in a bottom surface and a side surface thereof;

b) providing an L-shaped loading fixture defined as including a lower surface and a perpendicular side surface;

c) placing the rectangular wafer holder in relationship with said L-shaped loading fixture such that the wafer holder side surface is contiguous with the loading fixture lower surface and a top surface of the wafer holder is contiguous with the load fixture perpendicular side surface;

d) positioning a semiconductor wafer over the wafer holder front surface so as to cover the vacuum aperture,

said semiconductor wafer including a major flat and a minor flat, the major and minor flats formed to be orthogonal to one another;

e) adjusting the position of said semiconductor wafer until the major flat is contiguous with the loading fixture lower surface and the minor flat is contiguous with the loading fixture perpendicular side surface; and

f) applying a vacuum to said wafer holder to maintain the semiconductor wafer in the aligned position achieved in step e).

12. The method of aligning as defined in claim 11 wherein the method comprises the further steps of:

g) providing a corner cube exposure arrangement comprising a right-angle fixture defined by a first leg and a second leg, said fixture including a mirror surface formed on the first leg and a plurality of alignment features formed on the second leg of said right-angle fixture;

h) removing the wafer holder from the loading fixture and attaching said wafer holder to said corner cube exposure fixture such that the bottom surface of said wafer holder is contiguous with the second leg of the right-angle fixture and the side surface of said wafer holder is contiguous with the mirror surface of said right-angle fixture.

13. The method of aligning as defined in claim 12 wherein the wafer holder further comprises a first set of alignment features formed in the bottom surface thereof and a second set of alignment features formed in the side surface thereof, and the corner cube exposure arrangement further comprises a first set of alignment features formed in the second leg thereof and a second set of alignment features formed contiguous with the mirror surface, the method further comprising the step of:

i) adjusting the wafer holder with respect to the corner cube exposure arrangement such that the first set of wafer holder alignment features mates with the first set of corner cube exposure arrangement alignment features and the second set of wafer holder alignment features mates with the second set of corner cube exposure arrangement alignment features.

14. The method of aligning as defined in claim 13 wherein in performing step i), the corner cube second set of alignment features comprises an alignment channel and the adjusting includes sliding the wafer holder into position with respect to the corner cube alignment arrangement until the first set of wafer holder alignment features comes into intimate contact with the corner cube exposure arrangement first set of alignment features.

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Cole

(10) Patent No.: US 6,195,905 B1
(45) Date of Patent: Mar. 6, 2001

(54) METHOD OF VERIFYING THE STRAIGHTNESS OF THE ARBOR OF THE TABLE SAW

(76) Inventor: Jerry W. Cole, 8 Dodge Ct., Charlton, MA (US) 01507

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 09/055,896

(22) Filed: Apr. 6, 1998

Related U.S. Application Data

(62) Division of application No. 08/459,747, filed on Jun. 2, 1995, now Pat. No. 5,735,054.

(51) Int. Cl.[7] B23Q 17/00; B27G 23/00

(52) U.S. Cl. 33/640; 33/533; 33/633; 29/401.1; 29/407.01; 29/407.05; 83/477.2; 83/522.16

(58) Field of Search 83/477.2, 13, 522.16, 83/522.18; 33/202, 533, 628, 630, 632, 633, 634, 640; 29/401.1, 407.01, 407.05

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Primary Examiner—Clark F. Dexter
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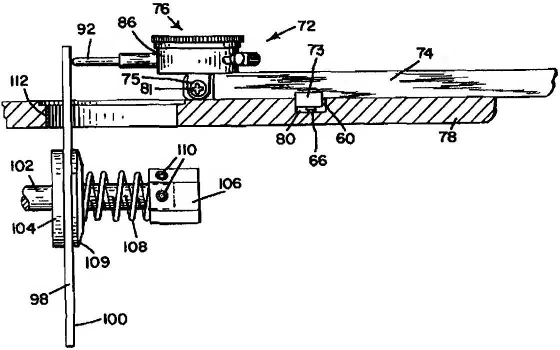
(57) ABSTRACT

A self-adjusting accessory for a table saw that includes a guide for sliding in the guide groove of the work supporting table of a table saw and which is biased against the edge of the guide groove which is closest to the cutting blade. The guide bar is used in conjunction with the plurality of table saw fixtures such as a miter gauge, an alignment gauge and a stop gauge. The alignment gauge also forms part of apparatus for carrying out a method of verifying the straightness of the arbor for the cutting blade, the alignment of the arbor relative to the guide groove of the work supporting table and the flatness of the cutting blade. The invention also includes an apparatus for adjusting the alignment of the arbor relative to the guide groove of the work supporting table.

3 Claims, 6 Drawing Sheets



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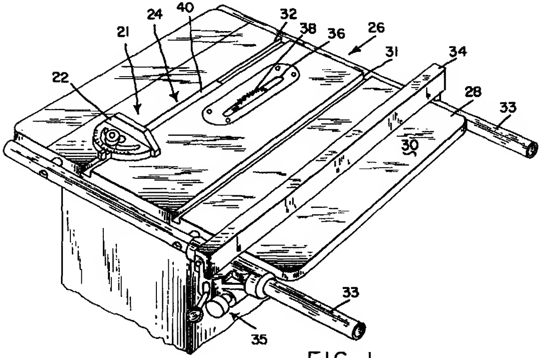

FIG. 1

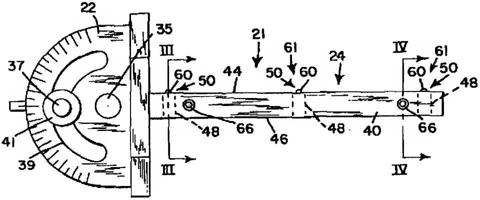

FIG. 2

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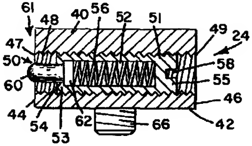

FIG. 3

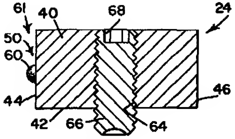

FIG. 4

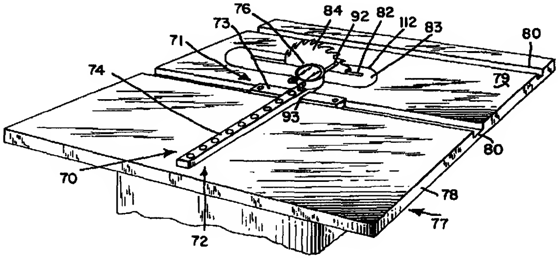

FIG. 5

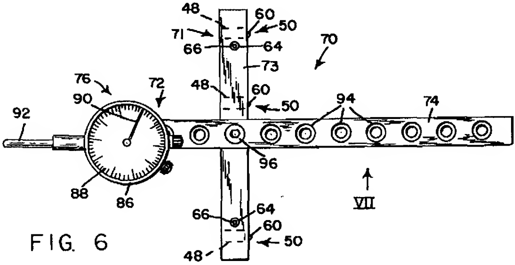

FIG. 6

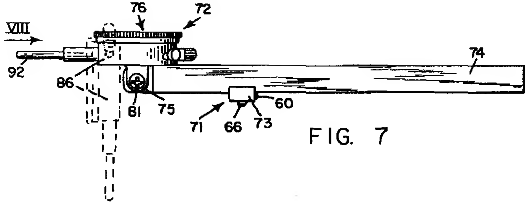

FIG. 7

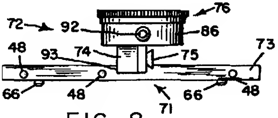

FIG. 8

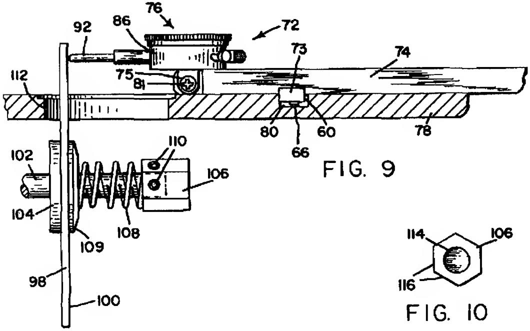

FIG. 9

FIG. 10

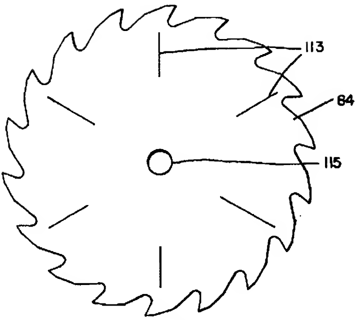

FIG. 11

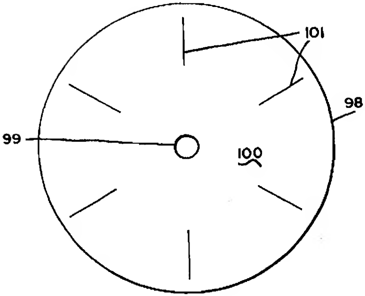

FIG. 12

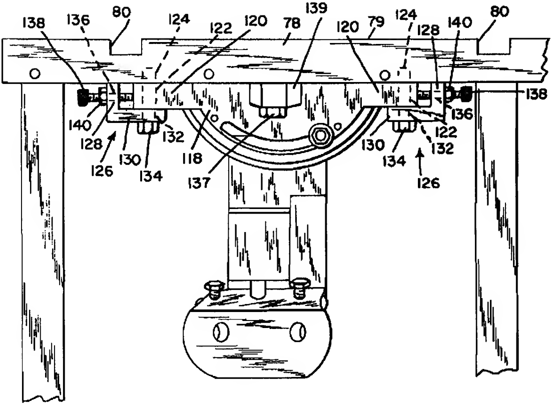

FIG. 13

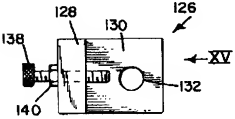

FIG. 14

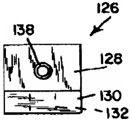

FIG. 15

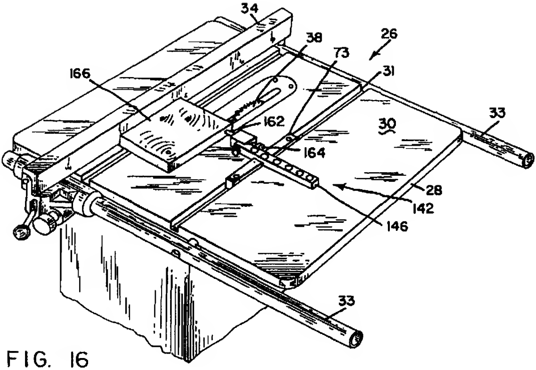

FIG. 16

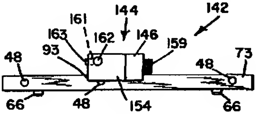

FIG. 18

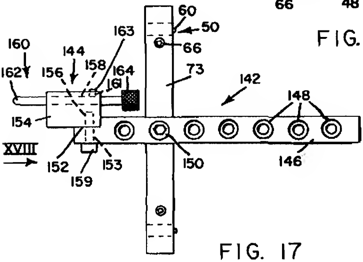

FIG. 17

METHOD OF VERIFYING THE STRAIGHTNESS OF THE ARBOR OF THE TABLE SAW

This application is a Divisional of U.S. Ser. No. 08/459, 747, filed Jun. 2, 1995 (U.S. Pat. No. 5,735,054).

BACKGROUND OF THE INVENTION

The present invention relates generally to a table saw fixture and particularly to a fixture and fixture combinations which provide accurate alignment to enable square cuts to be made on a workpiece. The invention also relates to a method of verifying the alignment of the arbor for the cutting blade, relative to the guide groove in the work supporting table of a table saw, as well as a method of and apparatus for adjusting the alignment of the arbor relative to the guide groove.

The modern table saw has a work supporting table which is provided with a slot and at least one guide groove in the upper surface of the table which is parallel with the slot. A circular cutting blade is mounted on an arbor which is rotatably mounted on a cradle which is connected to the table so that the blade extends through the slot in the table. The cradle is mounted on the table so that it can be raised or lowered and so that it can be rotated about a front to back horizontal axis. This enables the operator to adjust the amount of cutting height of the saw and the cutting angle of the saw, relative to the upper surface of the work supporting table.

The arbor supporting cradle in most modern table saws is pivotally mounted between a pair of trunnions. One trunnion is fastened to the bottom surface of the supporting table at the front end of the table saw. The other trunnion is fastened to the bottom surface of the supporting table at the rear end of the saw. The rear trunnion is fastened by bolts which extend through oversize holes in the rear trunnion. This enables the rear trunnion to be moved laterally a small amount, relative to the front trunnion, to correct for a possible misalignment of the arbor relative to the guide groove in the work supporting table. It is essential that the arbor be at a right angle to the guide groove so that the cutting blade is parallel with the guide groove of the supporting table. If the cutting blade is not parallel with the guide groove, the bolts which fasten the rear trunnion to the supporting table are loosened and the rear trunnion is forced into an adjusted position, for example by striking the trunnion with a hammer to move the rear trunnion laterally and to change the alignment of the cutting blade relative to the guide groove. This represents a crude and imprecise adjusting feature. It is extremely difficult to align the cutting blade relative to the guide groove with any degree of accuracy by the use of hammer blows. Also, even if an accurate alignment of the cutting blade is achieved, the achieved correct alignment can be lost when the bolts which hold the rear trunnion to the table are tightened.

The accurate cutting of a workpiece can be affected by factors other than the alignment of the cutting blade to the guide groove of the supporting table. These other factors include a cutting blade which may not be perfectly flat, an arbor which may not be perfectly straight and a guide groove which does not have a uniform width or is too wide for the guide bar of a fixture which is used for a cutting operation.

Verification devices have been developed for checking the alignment of the cutting blade with the guide groove of a table saw and for the flatness of the cutting blade. A typical verification device includes an elongated guide bar for slidable mounting in the guide slot of the work supporting table, a cross bar which is connected to the guide bar for supporting a gauge such as a feeler gauge which has a dial face, a dial and a plunger which is mounted on the gauge for axial movement relative to dial face and which is operatively connected to the dial. Although the gauge portion of the verification device is a very accurate instrument, inaccurate readings are obtained from the gauge due to a less than precise fit of the guide bar portion of the verification device within the guide groove and the lack of uniformity in the width of the groove. One prior art specification device utilizes a split bar which can be adjusted to fit into the guide slot by screws which are threaded into the bar. However, the device must be readjusted for another application. Also, prior art verification device which employ a dial gauge are limited in the ways that they can be used, due to the manner in which the dial gauge is mounted on the cross bar.

Inaccurate cutting of a workpiece occurs even if the longitudinal axis of the arbor is properly aligned with the guide groove and the guide bar of the fixture, such as a miter gauge, fits perfectly in a perfectly uniform guide groove. Inaccurate cuttings can occur if the arbor is not straight or if the cutting blade is not flat. If the arbor is straight and the guide bar of the fixture fits perfectly in the guide groove of the table saw, a misalignment of the arbor relative to the guide groove or a warp in the cutting blade can be detected by existing verification devices. However, there is no effective way to determine the straightness of the arbor without removing the arbor from the table saw or of making a proper adjustment of the arbor if one or more other variables which affect alignment are present. If there are errors or flaws in two or more variables, it is very difficult to verify and isolate the flaws and to correct them.

Proper alignment of the cutting blade and fixtures is particularly critical when the table saw is used for cutting very thin strips from a workpiece, i.e. for cutting veneer strips. For such thin pieces, uniformity of thickness is critical. Cutting accuracy must be maintained with low tolerance for error. Also, there is a lower limit to the width of strip which can be cut on a table saw by using conventional equipment and methods. Still further, precise cuts are extremely difficult to obtain on a conventional table saw, using conventional fixtures. These and other difficulties experienced with the prior art table saws, table saw fixtures, and method of using the fixtures with table saws have been obviated by the present invention.

It is, therefore, a principal object of the invention to provide a verification apparatus for checking all variables in a conventional table saw which contribute to alignment errors between the cutting blade and guide groove in the work supporting table of the table saw.

Another object of the invention is the provision of a method of checking and measuring all variables in a conventional table saw which contribute to alignment errors between the cutting blade and the guide groove in the work supporting table of the table saw.

A further object of the invention is the provision of an apparatus for and a method of positively and precisely aligning the arbor of a table saw relative to the guide groove in the work supporting table of the table saw.

It is another object of the invention to provide a self-adjusting guide bar for sliding in the guide groove of a table saw for use with a plurality of saw fixtures and which maintains a constant and precise relationship between the fixture and the cutting blade of the table saw.

A still further object of the invention is the provision of an alignment gauge which has improved precision and versatility.

S066

It is a further object of the invention to provide a locating gauge for use in a table saw to enable narrow pieces to be cut from a workpiece with improved accuracy and uniformity.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts and steps set forth in the specification and covered by the claims appended hereto.

SUMMARY OF THE INVENTION

The present invention includes an accessory for a table saw which has a fixture which is connected to a self-adjusting guide mechanism for sliding in the guide groove in the upper surface of the work supporting table of a table saw. The guide mechanism includes an elongated bar for sliding in the guide groove and at least two spaced yieldable compensators which protrude from one vertical side surface of the bar for engaging one of the side surfaces of the guide groove of the supporting table to maintain the opposite vertical side surface at the bar snugly against the opposite side surface of the guide groove. More specifically, each compensator includes a horizontal bore in the guide bar, a plunger for extending beyond one of the vertical side surfaces of the bar, a stop for limiting the amount by which the compensators protrude beyond the side surface of the bar, and means for biasing the plunger against the stop. In one form of the invention, the fixture is a miter gauge. In a second form of the invention, the fixture is an alignment gauge. In a still further form of the invention, the fixture is a work locating gauge for cutting narrow strips from a workpiece. The present invention also includes a method of verifying the straightness of the arbor on which the cutting blade is mounted in the axial alignment of the arbor relative to the guide groove of the table saw. The straightness of the arbor in a table saw is preferably verified by applying a reference plate which has a flat reference surface and a bore which is transverse to the reference surface onto the arbor of a table saw so that the reference plate rests against the conventional cutting blade locating stop of the arbor and the reference surface of the reference plate faces the guide groove of the table saw. The straightness of the arbor can be checked by a saw blade which is not necessarily perfectly flat as long as the saw blade remains stationary. An alignment gauge is applied to the guide groove of the table saw. The alignment gauge has an elongated guide bar for sliding in the guide groove and a cross bar which supports a dial gauge and a feeler rod which is slidingly mounted relative to the dial gauge for movement toward and away from the reference surface of the reference plate. The alignment gauge is positioned so that the feeler rod engages the surface of a reference plate and the arbor is rotated to a plurality of angular positions relative to the reference plate while maintaining the reference plate in a fixed position so that gauge readings can be taken at each of the angular positions. The right angle alignment of the arbor can be verified by applying the reference plate to the arbor so the plate extends through the slot for the cutting blade in the work supporting table and above the upper surface of the table. The alignment gauge is applied to the saw so that the guide bar of the gauge is slidably mounted in the guide groove and the feeler rod of the dial gauge extends to the reference surface of the reference plate. The alignment gauge is positioned at a first point in the guide groove of the work supporting table so that the feeler rod engages a first point at the front of the reference surface of the reference plate to obtain a first gauge reading. The dial gauge is then positioned at a second point along the guide groove of the work supporting table saw so that the feeler rod engages a second point at the rear of the reference surface of the reference plate to obtain a second gauge reading. The first and second readings are compared to determine if the arbor is at a right angle to the guide groove. In addition to the reference plate, the apparatus for verifying the straightness of the arbor in a table saw also includes a cap which is fixed to the free end of the arbor and a compression spring for mounting on the arbor between the reference plate and the cap to bias the reference plate against the stop on the arbor. This enables the arbor to be rotated relative to the reference plate and stopped at periodic increments of rotation so that a gauge reading can be taken each time that the arbor stopped.

The present invention also includes a method of and an apparatus for changing the alignment of the arbor if it is determined by the verification apparatus and method that the arbor of the present invention is not at a right angle to the guide groove of the supporting table. The alignment apparatus and method of the present invention are applicable to table saws in which the arbor is supported for rotation on a cradle which is, in turn, pivotally mounted between a pair of trunnions wherein each trunnion has a pair of flanges which enable the trunnion to be connected to the work supporting table by a pair of bolts. Each flange has a vertical aperture which is vertically aligned with a threaded vertical aperture in the work supporting table. The alignment apparatus of the present invention includes a pair of L-shaped brackets having a vertical leg and a horizontal leg. The vertical leg has a threaded aperture for receiving an adjusting screw. The horizontal leg has a vertical hole for receiving a bolt. Realignment of the arbor is accomplished by removing the bolts, one at a time, which connect one of the trunnions to the work supporting table of the table saw and positioning the brackets at opposite sides of the trunnion so that the horizontal leg portions of the brackets are below the flanges of the trunnion and the hole in the horizontal leg of each bracket is vertically aligned with the aperture in the flange with which the horizontal leg is engaged. A bolt is extended through the hole in the horizontal leg portion of each bracket and the aperture of the corresponding flange of the trunnion. The bolts are threaded into the threaded apertures in the table to support the L-shaped brackets and the trunnion but not tightened so that the trunnion is loosely connected to the supporting table and the trunnion is free to be moved laterally a slight amount. The trunnion is moved laterally to change the alignment of the arbor by rotating one of the adjusting screws until it engages the end edge of the flange. Additional rotation of the adjusting screw causes the trunnion to move laterally toward the other L-shaped bracket until the arbor is at a right angle to the guide groove of the table saw as verified by the verification apparatus of the present invention. The other adjusting screw is then advanced until it touches the edge of the opposite flange of the trunnion so that the trunnion is essentially locked in its correct position with respect to the right angle alignment of the arbor with the guide groove of the work supporting table. Each adjusting screw is provided with a lock nut to make sure that the trunnion remains in the correct set position. The trunnion bolts can then be tightened to secure the trunnion in the correct adjusted position.

BRIEF DESCRIPTION OF THE DRAWINGS

The character of the invention, however, may be best understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

FIG. 1 is a perspective view of a miter gauge embodying the self-adjusting accessory principle of the present inven-

S067

tion and shown applied to the supporting table of a conventional table saw;

FIG. 2 is a top plan view of the miter gauge;

FIG. 3 is a vertical cross-sectional view of the miter gauge, taken along the line III—III of FIG. 2 and looking in the direction of the arrows;

FIG. 4 is a vertical cross-sectional view of the miter gauge, taken along the line IV—IV of FIG. 2 and looking in the direction of the arrows;

FIG. 5 is a perspective view of an alignment gauge embodying the self-adjusting accessory principle of the present invention and shown applied to the supporting table of a conventional table saw;

FIG. 6 is a top plan view of the alignment gauge;

FIG. 7 is a side elevational view of the alignment gauge, looking in the direction of arrow VII of FIG. 6;

FIG. 8 is an end view of the alignment gauge, looking in the direction of arrow 8 of FIG. 7;

FIG. 9 is a side elevation view of apparatus which is used for verifying the straightness of the arbor of the table saw which includes the alignment gauge of FIGS. 6–8;

FIG. 10 is an end view the cap portion of the apparatus for verifying the arbor straightness;

FIG. 11 is a face view of a cutting blade for a table saw;

FIG. 12 is a face view of the reference surface of a reference plate which forms part of the verification apparatus of FIG. 9;

FIG. 13 is a rear elevation view of apparatus for aligning the arbor of a table saw relative to the guide groove in the supporting table of the table saw and shown applied to the back arbor supporting trunnion of the table saw;

FIG. 14 is a top plan view of the arbor aligning apparatus of FIG. 13;

FIG. 15 is an end view of the arbor aligning apparatus, looking in the direction of arrow XV of FIG. 14;

FIG. 16 is a perspective view of a workpiece locating gauge which embodies a self-adjusting accessory principle of the present invention and shown applied to the supporting table of a conventional table saw;

FIG. 17 is a top plan view of the workpiece locating gauge; and

FIG. 18 is an end view of the workpiece locating gauge, looking in the direction of arrow XVIII of FIG. 17.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIGS. 1–4 there is shown a self-adjusting accessory which is generally indicated by the reference numeral 21 and shown applied to the supporting table of a conventional table saw which is generally indicated by the reference numeral 26. The table saw 26 includes a workpiece supporting table 28 which has an upper surface 30 which contains a pair of guide grooves 31 and 32. The table saw 26 also includes a ripping fence 34 which rests on the surface 30 and which is slidably mounted on a pair of guide rails 33. The ripping fence 34 can be locked in any desired position on the supporting surface 30 by a locking mechanism, generally indicated by the reference numeral 35 a cutting blade 38 extends through a slot 36 in upper surface 30.

The self-adjusting accessory 21 includes a miter gauge 22 which is pivotally connected to a guide mechanism, generally indicated by the reference numeral 24, by means of a pivot pin 25. The guide mechanism 24 includes an elongated bar 40 which contains a plurality of horizontal threaded bores 48. Each of the bores 48 contains a moveable plunger which is generally indicated by the reference numeral 50. A screw 37 is fixed to one end of the bar 40 and extends upwardly through an arcuate slot 39 in the miter gauge 22. A locking nut 41 is threaded to the upper end of the screw 37 for locking the miter gauge 22 to the bar 40 in any desired angle of position of the bar 40, relative to the miter gauge.

Referring particularly to FIG. 3, each horizontal bore 48 has a first opening 47 in a first vertical side surface 44, and a second opening 49 in the second vertical side surface 46. The bore 48 has internal threads which correspond to the external threads of a plug 51 which is threaded into the bore 48 as shown in FIG. 3. The plug 51 has a chamber 52, a first end wall 53 is adjacent the opening 47, and a second end wall 55 which is adjacent the opening 49. The end wall 55 has a groove 58 for receiving the blade of a screwdriver for rotating the plug 51 to selectively advance the plug 51 toward the opening 47 or to retract the plug 51 toward the opening 49. The first end wall 53 has an opening 54 into the chamber 52. The plunger 50 has a relatively wide portion 62 which is slidably mounted within the chamber 52 and a relatively narrow portion 60 which extends through the opening 54 in the wall 53 and through the opening 47 in the first vertical side surface 44. A compression spring 56 is located within the chamber 52 for biasing the relatively wide portion 62 of the plunger against the first end wall 53 so that the free end of the relatively narrow portion 60 of the plunger extends to an outer position beyond the first vertical side surface 44. The plunger 50 is movable axially against the bias of the spring 56 to an inner position wherein the outer end of the relatively narrow portion 60 of the plunger is at least flush with the first vertical side surface 44. The plug 51 functions as an adjustable stop mechanism for limiting the outward extension of the free end of the plunger to determine the outer position of the free end of the plunger. The outer position of the free end of the plunger can be changed by rotating the plug 51 within the bore 48. The plug 51, plunger 50 and spring 56 constitute a yieldable compensator, generally indicatd by the reference numeral 61.

The miter gauge 22 is positioned on the work supporting table of the table saw, as shown in FIG. 1, so that the guide bar 40 is slidably mounted within the guide groove 32. The free ends of the plunger 50 bear against the vertical side surface of the groove which is furthest from and faces the cutting blade. The plungers 50 bias the second vertical side surface of the guide bar 40 against the vertical side surface of the groove 32 which is closest to and faces away from the cutting blade 38. This insures that the vertical side surface 46 will always be flush with the vertical side surface of the groove which faces away from the cutting blade 38 and which is closest to the cutting blade 38, regardless of how well the guide bar 40 fits within the groove 32 or whether or not the guide groove 32 is uniform in width. If the operator prefers to use the groove 31 on the opposite side of the cutting blade 38, the plugs 51 are removed from the bores 48 and reinserted into the bores through the openings 47 so that the narrow portions 60 of the plungers extend through the openings 49. In this orientation, the first vertical side surface 44 is biased flush against the vertical side surface of the groove 31 which faces away from and is closest to the cutting blade 38.

Referring particularly to FIG. 4, the guide bar 40 has a pair of vertical threaded bores 64. An adjusting screw 66 is threaded into each bore 64 from the top so that the lower end

of the screw extends below the bottom surface 42 of the guide bar 40. The upper end of the screw 66 has a hex socket 68 for receiving an allen wrench for adjusting the vertical position of the adjusting screw 66. The adjusting screw 66 provides a vertical adjustment feature for the guide bar 40 to adapt the guide bar to the depth of the guide groove in the work supporting table of the table saw. Guide groove depths vary considerably between different makes of table saws. The height of the guide bar 40 is adjusted so that the top of the guide bar is flush with the top surface of the work supporting table and the fixture to which it is attached such as the miter gauge 22 is flush with the upper surface of the work supporting table. The primary purpose of the adjusting screws 66 is to prevent the guide bar 40 from rocking within the guide groove.

Referring to FIGS. 5–8, there is shown a self-adjusting accessory for a table saw which is generally indicated by the reference numeral 70. The fixture of the accessory 70 is an alignment gauge which is generally indicated by the reference numeral 72. The alignment gauge 72 includes a dial gauge, generally indicated by the reference numeral 76, which is pivotally mounted on a horizontal cross bar 74 for pivoting movement about a horizontal axis by means of a pivot pin 75. The cross bar 74 is connected to a guide mechanism 71 which includes an elongated guide bar 73 that extends transversely of the cross bar 74 as shown in FIG. 6. The guide bar 73 is similar to the guide bar 24 which was described previously. The guide bar 73 contains a plurality of threaded bores 48 which contain the plungers 50 and plugs 51 which are illustrated in FIG. 3. The elongated guide bar 73 also includes a plurality of vertical bores 64, each of which contains one adjusting screw 66 which is shown in FIG. 4 for vertically adjusting the guide bars 73 within the guide groove of the work supporting table of the table saw. The bar 73 differs from the bar 24 in that it has a threaded vertical aperture at a midpoint of the bar for receiving a screw 96 for connecting the cross bar 74 to the guide bar 73. The upper surface of the guide bar 73 has a horizontal slot 93 for receiving the lower end of the cross bar 74 to maintain the guide bar 73 at a right angle to the cross bar 74. The cross bar 74 has a plurality of vertical apertures 94. The screw 96 extends freely through any one of the apertures 94 and is threaded into the threaded aperture in the middle of the bar 73 to enable the cross bar 74 to be mounted on the guide bar 73 at a plurality of positions along the length of the cross bar 74. This enables the accessory 70 to be used with different makes of table saws which vary in the location of the guide groove 80 relative to the cutting blade of the table saw. The screws 66 are adjusted so that the guide bar extends above the surface of the work supporting table and the bottom surface of the cross bar 74 is flush with the top surface of the work supporting table. The dial gauge 76 is a commercially available gauge such as a model number 605-4070 manufactured by Enco Company. The dial gauge 76 includes a circular housing 86, a dial face 88, a dial 90, and an elongated feeler rod 92 which is slidably mounted into the housing for movement longitudinally of the cross bar 74. The feeler rod 92 has a free end which extends beyond the end of the housing 86 and the cross bar 74.

The accessory 70 has multiple functions, including that of an alignment gauge for verifying the alignment of the cutting blade of a table saw relative to the guide groove in the work supporting table of the table saw or for verifying the flatness of the cutting blade. Referring to FIG. 5, the accessory 70 is employed as an alignment gauge by positioning the guide bar 73 within the guide groove 80 of the upper surface 79 of a work supporting table 78 which forms part of a table saw, generally indicated by the reference numeral 77. The work supporting table 78 of the table saw 77 also includes a vertical slot 82 through which a cutting blade 84 extends. The guide bar 73 is located in the groove 80 so that the free end of the elongated feeler rod 92 engages the face of the cutter blade 84 at a first point to obtain a first reading of the dial 90. The guide bar 73 is then moved longitudinally along the guide groove 80 so that the free end of the feeler rod 92 engages a second point on the cutting blade 84 to obtain a second reading of the dial 90. The second reading of the dial 90 is then compared with the first reading for verification of the alignment or flatness of the cutting blade 84, relative to the guide groove 80. The plungers 50 maintain the vertical side surface of the guide bar 73 which is closest to the cutting blade 84 flush against the vertical side surface of the guide groove 80 which is also closest to the cutting blade 84. This eliminates any errors in reading of the dial gauge which could be attributed to variations in the guide groove 80. The pivotal mounting of the alignment gauge 72 enables the dial gauge to be rotated about the pivot pin 75 to a plurality of positions between the horizontal full line position shown in FIG. 7 to the dotted line vertical position shown in FIG. 7. The pivot pin 75 is threaded into the cross bar 74 and is provided with a socket 81 for receiving a corresponding tool for rotating the pin 75 for loosening or tightening the pin 75. This enables the gauge 72 to be adjusted relative to the cross bar 74 so that the free end of the feeler rod 92 engages the face of the cutting blade 84 at a point very close to the top surface 79 of the work supporting table 78. This enables readings to be taken at two separate points on the face of the cutting blade 84 which are considerably further apart than would be possible along a horizontal line which is spaced substantially above the top surface 79 of the work supporting table. This provides a more accurate reading since any variation in the alignment of the cutting blade relative to the guide groove of the work supporting table is more likely to be detected when taking measurements at two widely separated points as compared to taking measurements at two points which are closer together.

The accessory 70 of the present invention can also be utilized for measuring the right angle alignment of the arbor of a drill press relative to the work supporting table of the drill press. This is accomplished by positioning the cross bar 74 beneath the chuck of a drill press so that one of the apertures 94 is aligned with the aperture of the chuck and inserting a pin through the aperture of the cross bar and into the chuck opening. The chuck is tightened to secure the bolt. The dial gauge 76 is repositioned to the dotted line position shown in FIG. 7. The chuck of the drill press is then lowered so that the free end of the feeler rod 92 touches the top surface of the work supporting table of the drill press to obtain a first reading. The cross bar 74 is then rotated about the bolt which supports the cross bar and the chuck so that the free end of the feeler rod 92 engages a second point on a work supporting table of the drill press to obtain a second reading. A comparison of the two readings of the gauge 76 verifies if the chuck is at a right angle to the work supporting surface of the drill press.

Referring to FIGS. 9–12, the alignment gauge accessory 70 is utilized in conjunction with other elements for carrying out a method of checking for all variables which contribute to errors in the alignment of the cutting blade relative to the guide groove of the table saw and for verifying the alignment of the cutting blade. The additional elements of the apparatus for alignment verification include a reference plate 98 which has a flat reference surface 100 and a central

aperture 99. The surface 100 has a plurality of radial reference lines 101 which are evenly spaced at a predetermined number of degrees, as for example, every 60° as shown in FIG. 12. The plate 98 is adapted to be fixed onto the arbor 102 of the table saw and rests against the stop 104. The verification apparatus also includes a cap 106 which has a cylindrical socket 114 for receiving the free end of the arbor 102 as shown in FIG. 9. The cap 106 is fixed to the free end of the arbor 102 by means of set screws 110. A compression spring 108 is adapted to be mounted on the arbor 102 between the reference plate 98 and the cap 106 and, preferably, bears against a washer 109 which is located between the reference plate 98 and the spring 108. The side surface of the cap 106 is provided with a plurality of facets 116. In the example shown in FIGS. 9 and 10, the side surface of the cap 106 has six evenly spaced facets 116 and has the general appearance of a hex nut.

The procedure for verifying the alignment of the cutting blade of the table saw relative to the guide groove of the table saw begins by first removing a plate 83 which contains the slot 82 for the cutting blade to expose the larger slot 112 in the work supporting table 78 of the table saw.

The first procedure to be completed is the verification of the straightness of the arbor 102. This is accomplished by removing the cutting blade 84 and applying the reference plate 98 onto the arbor 102 so that it rests against the stop 104. The alignment guide 72 is then positioned on the work supporting table so that the cross bar 74 is located within the guide groove 80 and the elongated rod 92 engages the reference surface 100 of the reference plate. The basic method for verifying the straightness of the arbor 102 comprises maintaining the reference plate 98 stationary while rotating the arbor 102 for one complete revolution while pausing at regular angular increments to record readings from the dial gauge 76. Since the surface 100 is perfectly flat, the readings from the gauge 76 will be the same for all angular positions of the arbor 102 if the arbor is straight. A reference plate which has a reference surface which is not perfectly flat can also be used, as long as the reference plate is maintained in a stationary position. If the arbor 102 is crooked, the reading from the gauge 76 will be different. This procedure is facilitated by applying the washer 109 against the surface 100 of the reference plate 98 and applying the compression spring 108 onto the free end of the arbor 102. The cap 106 is then applied to the free end of the arbor 102 so that it compresses the spring 108. The cap 106 is fixed to the arbor by set screws 110. This provides a biasing force against the reference plate 98. The cap 106 provides a means for rotating the arbor 102 and the facets 116 serve as reference points to assist the operator in taking gauge readings at regular segments of rotation of the arbor 102. In the example shown FIGS. 9 and 10 the hexagonal shape of the cap 106 serves as a guide for six readings at 60° intervals.

When it is determined that the arbor 102 is straight, the next procedure is to verify the alignment of the arbor 102 relative to the guide groove 80 of the work supporting table 78. This is accomplished by applying the reference plate 98 and the washer 109 onto the arbor 102 so that the reference plate rest against the stop 104 and the washer 109 rest against the reference plate 98. The reference plate 98 is fixed to the arbor 102 by applying the same nut which is normally used to secure the cutting blade to the arbor so that it bears against the washer 109. The alignment gauge 72 is applied to the work supporting table as described above for checking the straightness of the arbor. A reading is taken at the front end of the reference plate and a reading is taken at the rear end of the reference plate. If the arbor 102 is at a right angle to the guide groove 80 within a vertical plane, the front and rear readings from the gauge 76 will be the same. If the arbor 102 is not at a right angle to the guide groove 80, the readings on the gauge 76 will differ, thereby indicating a misalignment of the arbor 102 relative to the guide groove of the work supporting table.

If it is determined, by using the procedures described above, that the arbor 102 is straight and that it is at a right angle alignment with the guide groove 80 of the work supporting table, the last procedure is to verify the flatness of the cutting blade 84 which is being used on the table saw the cutting blade 84 has a central aperture 115. This verification procedure is accomplished by mounting the cutting blade 84 to the arbor 102 in the same manner as the mounting of the reference plate 98 as shown in FIG. 9. The arbor 102 is then raised so that the cutting blade extends above the top surface 79 of the work supporting table to a maximum degree. The flatness of the cutting blade 84 is verified by drawing a plurality of radial lines 113 on the flat surface of the cutting blade which faces the guide groove 80. The radial lines 113 are spaced at even angular increments, for example at 60° intervals. The arbor 102 is maintained stationary and the cutting blade 84 is rotated for one revolution while pausing at every 60° of rotation, as guided by the reference lines 113, to take a reading from the dial gauge 76. If the cutting blade 84 is perfectly flat, all of the gauge readings will be the same. If the cutting blade 84 is warped, then the readings from the gauge 76 will be different. Once it has been determined that the arbor is straight and the cutting blade is flat, the alignment of the arbor 102 can be verified with the use of the alignment gauge 72. The dial gauge 76 is pivoted relative to the cross bar 74 so that the free end of the elongated rod 92 touches the face of the cutting blade 84 just above the upper surface 79 of the work supporting table 78. A first reading is taking at a first point on the cutting blade. The accessory 70 is then moved along the guide groove 80 so that a second reading can be taken at a second point the opposite end of the exposed portion of the cutting blade.

When it is discovered that the arbor 102 is misaligned relative to the guide groove 80 during an initial series of verification tests or at a subsequent time during use of a table saw, the arbor 102 is readjusted into a proper right angle alignment relative to the guide groove by the apparatus which is shown in FIGS. 13–15. The mechanism for aligning the arbor of the table saw comprise a pair of L-shaped brackets, generally indicated by the reference numeral 126, for use with a table saw in which the arbor is supported on a cradle which is, in turn, supported between a pair of trunnions. A front trunnion is located at the front of the table saw and a back trunnion is located at the back of the table saw. The back trunnion which is illustrated in FIG. 13, is generally indicated by the reference numeral 118 and includes a pair of horizontally extending flanges 120. Each flange 120 has an aperture 122 which is vertically aligned with a threaded aperture 124 in the work supporting table 78. A bolt 134 extends through the aperture 122 and is threaded into the aperture 124 to secure the trunnion 118 to the work supporting table 78. Each aperture 124 is wider than the bolt, at least in the lateral dimension, to enable the back trunnion 118 to be moved laterally relative to the work supporting table 78.

Each L-shaped bracket 126 comprises a vertical leg 128 which contains a horizontal threaded aperture 136 and a horizontal leg 130 which contains an aperture 132. If it is determined that realignment of the arbor is required. A

center bolt 137 is loosened, the bolt 137 extends freely through an oversize aperture in a flange 139 of the trunnion 118 and is threaded into the supporting table 78. The bolts which hold the back trunnion 118 to the work supporting table 78 are removed and an L-shaped bracket 126 is positioned beneath each of the flanges 120 so that the aperture 132 of each bracket is vertically aligned with the adjacent apertures 122 and 124. A bolt 134 which is slightly longer than the original bolts which held the back trunnion is inserted into the apertures 132 and 122 and is then threaded into the aperture 124, sufficiently to support the back trunnion 118 but not tight enough to prevent the back trunnion from being shifted laterally. The aperture 122 is substantially larger in diameter, at least in the lateral dimension, than the bolt 134 to allow for lateral shifting of the back trunnion 118. Each L-shaped bracket 126 includes an adjusting (or set) screw 138 which is threaded into the aperture 136. After it has been determined which direction the back trunnion 118 must be shifted in order to bring the arbor into alignment with the guide groove of the work supporting table, the set screw 138 on the L-shaped bracket 126, from which movement of the cradle 118 must occur to achieve correct alignment of the arbor, is advanced toward the adjacent flange 120 until it engages the end of the flange. The adjusting screw 138 is then advanced an additional amount to shift the trunnion 118 relative to the L-shaped bracket 126 and to the work supporting table 78 until the arbor is at a right angle to the guide groove of the work supporting table. At this point, the adjusting screw 138 of the opposite L-shaped bracket 126 is advanced until it engages the end of the adjacent flange 120. A locking nut 140 is threaded onto each adjusting screw 138 between the head of the screw and the outer surface of the vertical leg portion 128. When the back trunnion 118 has been correctly positioned and each adjusting screw 138 is in engagement with its respective flange 120, the center bolt 137 is tightened. The lock nuts 140 are then advanced toward their respective vertical leg portions 128 so that the set screws 138 will remain in their set position and the trunnion 118 will be prevented from shifting laterally out of adjustment during subsequent operation of the table saw. The bolts 134 are tightened to fully secure the back trunnion 118 to the work supporting table 78.

Referring to FIGS. 16–18, there is shown a third self-adjusting accessory of the present invention which is generally indicated by the reference numeral 142. The accessory 142 includes a stop gauge, generally indicated by the reference numeral 144, which is connected to the bar 73 which is utilized with the alignment gauge 72 to form the accessory 70. The stop gauge 144 includes a cross bar 146 which has a plurality of vertical apertures 148 which enable the cross bar 146 to be mounted within the slot 93 of the guide bar 73 at a plurality of positions along the length of the cross bar 146 by means of an allen screw 150. One end of the cross bar 146 has a notch 152 and a horizontal aperture 153 which extends to the notch 152. A generally rectangular block (or housing) 154 is located within the notch 152 and has a horizontal threaded aperture 156 which is horizontally aligned with the aperture 153 of the cross bar 146. A screw 159 is threaded into the aperture 156 for securing the block 154 to the cross bar 146. The block 154 also has a threaded horizontal aperture 158 which is at a right angle to the aperture 153. The threaded shank portion 162 of an adjusting screw or rod, generally indicated by the reference numeral 160, is threaded into the aperture 158. The adjusting screw 160 has a head portion 164 which has a knurled outer surface to enable the adjusting screw to be manually adjusted by axial rotation of the adjusting screw within the threaded aperture 158. Alternatively, the block 154 may include a threaded aperture 161 which intersects threaded aperture or bore 148, and a set screw 163 which is threaded into aperture 161 for releasably locking the screw (or rod) 160 in any adjusted position.

The stop gauge 144 is used as a locating tool for a workpiece to enable narrow strips to be cut from a workpiece, particularly for strips which are too narrow to be safely cut along the ripping fence of the table saw in a traditional manner. If the strips to be cut are too narrow, they are difficult to push through the saw between the cutting blade and the ripping fence.

The stop gauge 144 of the present application is utilized by placing the guide bar 73 in the guide groove 31 in the work supporting table 28 of the table saw 26 so that the free end of the adjusting screw 160 extends toward the cutting blade 38. The screw 160 is adjusted so that the distance between the free end of the adjusting screw and the flat surface of the cutting blade is equal to the width of the strip which is to be cut from the workpiece the block 154 has a threaded aperture 161 which intersects aperture 158 for receiving a set screw 163. In contrast to the other fixtures which are utilized with the elongated guide bar 73, the vertical side surface of the guide bar which is farthest from the cutting blade is maintained snugly against the vertical side surface of the guide groove 31 which is also farthest from the cutting blade, due to the biasing action of the plungers 50. When the free end of the adjusting screw 160 has been adjusted to its desired position, it is locked in position by the set screw 163. The workpiece, which is generally indicated by the reference numeral 166, is positioned on the upper surface 30 of the work supporting table 28 so that the side edge of the workpiece engages the free end of the adjusting screw 160, as shown in FIG. 16. The ripping fence 34 is then adjusted along the upper surface of the table 28 until it engages the opposite side edge of the workpiece 166. At this point, the ripping fence 34 is locked in position. The workpiece 166 is then pushed through the cutting blade 38, which results in the cutting of a strip from the workpiece of a desired width. If another piece having the same width as the first piece is to be cut from the workpiece, the workpiece is repositioned against the free end of the adjusting screw 160. The fence 34 is readjusted to engage the opposite side edge of the workpiece and is secured in this position as before. The workpiece 166 is advanced through the cutting blade 38 to produce a second narrow strip which is identical to the first strip. This procedure can be repeated to produce as many identical narrow strips as desired. The self-adjusting accessory 142, which employs the stop gauge 144, can be utilized with a cross cut fixture for cutting a plurality of pieces of the same length from a long workpiece. The stop gauge 144 is positioned so that the free end of the adjusting screw (or rod) 160 is positioned from the cutting blade 38 at a distance which is equal to the length of the pieces to be cut. A long workpiece is positioned on the work supporting table so that the end of the workpiece engages the end of the adjusting screw 160.

Alternatively, the block 154 may include a threaded aperture 161 which intersects threaded aperture or bore 148, and a set screw 163 which is threaded into aperture 161 for releasably locking the screw (or rod) 160 in any adjusted position. The workpiece is then advanced through the saw 38. Subsequent equal length pieces can be cut from the workpiece by repeating this procedure.

The cross bar 146 of the accessory 142 is nearly identical to the cross bar 74 of the accessory 72 so that the stop gauge

144 and the alignment gauge 72 can be used interchangeably with either cross bar.

Clearly, minor changes may be made in the form and construction of this invention and in the embodiments of the process without departing from the material spirit of either. Therefore, it is not desired to confine the invention to the exact forms shown herein and described but it is desired to include all subject matter that properly comes within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

1. A method of verifying the straightness of an arbor in a table saw which has a work supporting table and a guide groove in the upper surface of the table, wherein the arbor has a central longitudinal axis, a free end and a stop which is spaced from the free end of the arbor, and wherein the guide groove extends transversely of the central longitudinal axis of the arbor, said method comprising:

(a) applying a reference plate which has a flat reference surface and a bore which is transverse to the reference surface onto the arbor of the table saw so that the reference plate rests against the stop of the arbor and the reference surface of the reference plate faces the guide groove in the upper surface of the table saw;

(b) applying a compression spring onto the arbor of the table saw;

(c) applying a cap onto the free end of the arbor of the table saw so that the compression spring is compressed and exerts a biassing force against the reference plate;

(d) removably fixing the cap to the free end of the arbor;

(e) applying an alignment gauge in the guide groove of the table saw, the alignment gauge having an elongated guide bar slidably disposed in the guide groove of the table saw, a cross bar which is mounted on the guide bar so that it extends transversely of the guide bar, a dial gauge which is mounted on the cross bar, and a feeler rod which is slidably mounted relative to the dial gauge for movement toward and away from the reference surface of the reference plate;

(f) positioning the alignment gauge on the table saw so that the feeler rod engages the reference surface of the reference plate; and

(g) maintaining the reference plate in a fixed position relative to the work supporting table and incrementally rotating the arbor of the table saw to a plurality of angular positions for at least one complete revolution of the arbor so that gauge readings can be taken at each of said angular positions.

2. A method of verifying the straightness of an arbor in a table saw which has a work supporting table, a slot in the supporting table for the cutting blade and a guide groove in the upper surface of the table, wherein the arbor has a central longitudinal axis, a free end and a stop which is spaced from the free end of the arbor, and wherein the guide groove extends transversely of the central longitudinal axis of the central longitudinal axis of the arbor, said method comprising:

(a) applying a reference plate which has a flat reference surface and a bore which is transverse to the reference surface onto the arbor of the table saw so that the reference plate rests against the stop of the arbor, a portion of the reference plate extends through the slot in the work supporting table and above the upper surface of the table, and the reference surface of the reference plate faces the guide groove in the upper surface of the table saw;

(b) applying an alignment gauge in the guide groove of the table saw, the alignment gauge having an elongated guide bar slidably disposed in the guide groove of the table saw, a cross bar which is mounted on the guide bar so that it extends transversely of the guide bar, a dial gauge which is mounted on the cross bar, and a feeler rod which is slidably mounted relative to the dial gauge for movement toward and away from the reference surface of the reference plate;

(c) positioning the alignment gauge on the table saw so that the feeler rod engages the reference surface of the reference plate;

(d) maintaining the reference plate in a fixed position relative to the work supporting table and incrementally rotating the arbor of the table saw to a plurality of angular positions relative to the reference plate for at least one complete revolution of the arbor so that gauge readings can be taken at each of said angular positions.

3. A method of verifying the right angle alignment of an arbor of a table saw to a guide groove in the upper surface of the supporting table of the table saw, wherein the arbor has a central longitudinal axis, a free end and a stop which is spaced from the free end of the arbor, and wherein the guide groove extends transversely of the central longitudinal axis of the arbor, said method comprising:

(a) applying a reference plate which has a flat reference surface and a bore which is transverse to the reference surface onto the arbor of the table saw so that the reference plate rests against the stop of the arbor and the reference surface of the reference plate faces the guide groove in the upper surface of the table saw;

(b) fixing the reference plate to the arbor of the table saw;

(c) applying an alignment gauge in the guide groove of the table saw, the alignment gauge having an elongated guide bar for sliding in the guide groove of the table saw, a cross bar which is mounted on the guide bar so that it extends transversely of the guide bar, a dial gauge which is mounted on the cross bar, and a feeler rod which is slidably mounted relative to the dial gauge for movement toward and away from the reference surface of the reference plate;

(d) positioning the alignment gauge at a first point in the guide groove of the table saw so that the feeler rod engages a first point on the reference surface of the reference plate to obtain a first gauge reading; and

(e) positioning the alignment gauge at a second point in the guide groove of the of the table saw so that the feeler rod engages a second point on the reference surface of the reference plate to obtain a second gauge reading.

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Keys et al.

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(45) **Date of Patent: Jun. 25, 2002**

(54) **S-GAUGE**

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(58) **Field of Search** .... 33/199 R, 522, 33/833, 832, 551, 549, 679.1, 199 B, 553, 555

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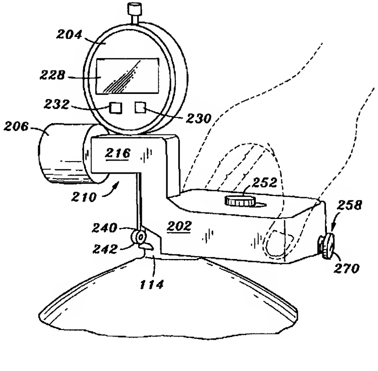
(57) **ABSTRACT**

A measuring device for measuring the thread start distance of a thread formed on an outer surface of a container finish is provided. The measuring device includes a base having a first surface for receiving a rim of a container finish, a support member, a gauge, and a counterweight to balance the measuring device on the finish. The support member is movably attached to the base and adjacent the first surface. A side surface of the support element is in contact with the container finish. The gauge is attached to the base and a gauge actuator having a roller contact member is operatively associated with the gauge. The gauge actuator measures the distance between the rim of the container finish and a thread start point of the thread of the container finish, S-dimension, as the gauge actuator moves along an upper base line of the thread.

19 Claims, 5 Drawing Sheets



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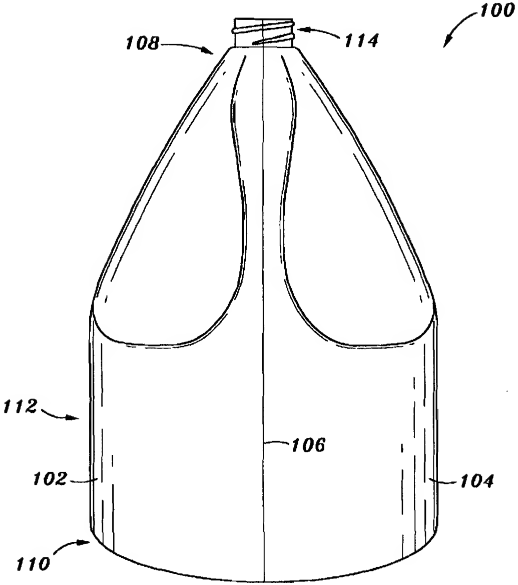

Fig. 1

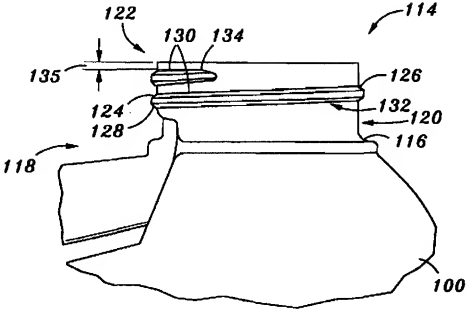

Fig. 2A

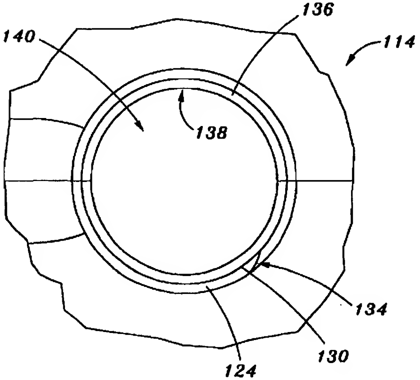

Fig. 2B

5075

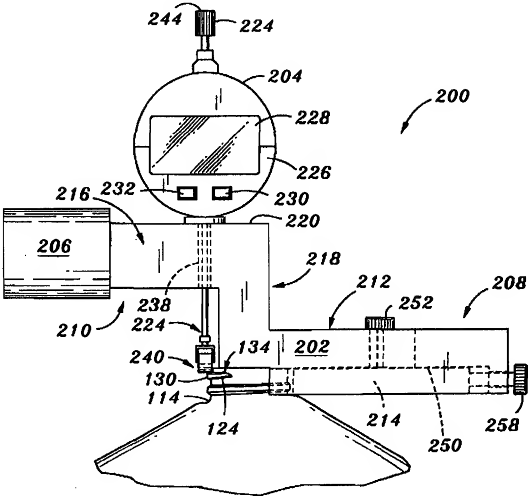

Fig. 3A

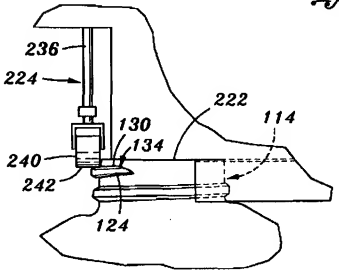

Fig. 3B

5076

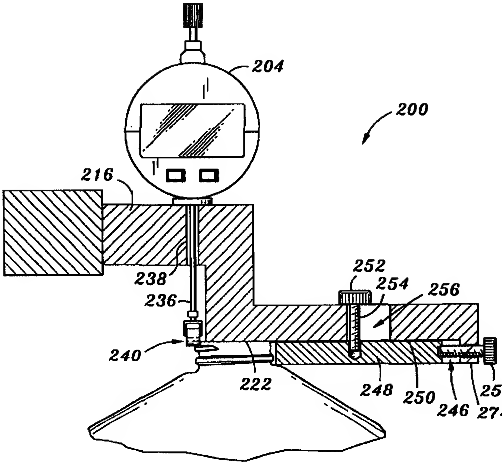
204
200
216
238
236
240
222
252
254
256
248
250
246
274
258

Fig. 3C

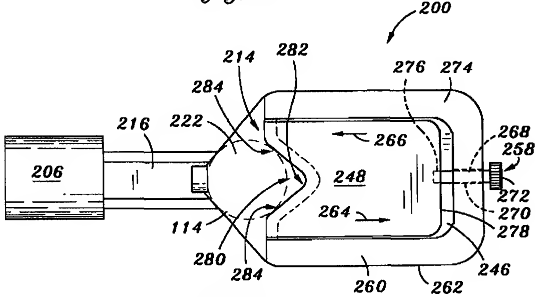
200
214
282
284
276
274
216
222
266
268
258
206
248
272
270
264
278
114
280
284
260
262
246

Fig. 4

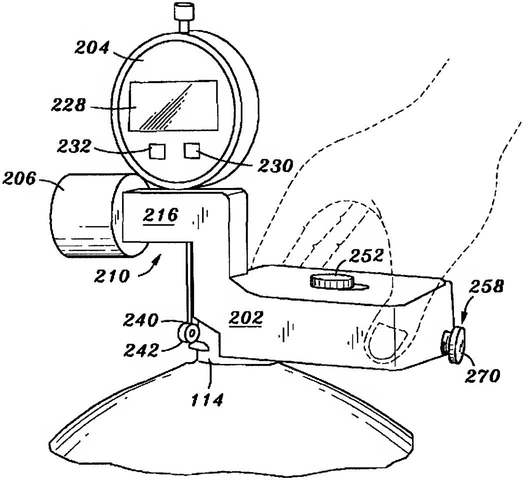

Fig. 5

S-GAUGE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to measuring devices and, more particularly, to a device for measuring an S-dimension of container finishes.

2. Description of the Related Art

In the manufacture of containers, certain dimensions are required to be within predetermined tolerance limits in order for the containers to function properly. In particular, the upper surface of the container, commonly known as the finish, must be maintained within certain manufacturing tolerances in order to provide adequate cap retention for a liquid tight seal to be formed between the container finish and the container cap.

Variations in the dimensions of containers, particularly plastic containers, may occur during molding or trimming operations due to many factors, including differences in the molds used to form the containers, shrinkage of the containers after molding, materials used, curing temperatures, and trimming operations.

In order to determine whether produced containers, such as bottles, are within predetermined dimensional tolerances, generally a sampling of the bottles being produced is measured to determine actual dimensions. This is especially true for the finish (i.e., neck portion) of the bottles. For bottles which will hold fluids, including consumer products such as detergents and bleaches, it is important that the S-dimension (i.e., start of thread dimension) is within predetermined dimensional tolerances so that a bottle cap will be retained properly on the finish and leaks will be prevented. The S-dimension is defined as the distance between the top of the sealing surface and the top of the thread or the uppermost location where a thread can extend as it is extended around the finish. The S-dimension is measured from the minor diameter of the thread or the base of the thread where the thread adjoins the outer wall of the finish.

The S-dimension of a container finish can be determined by manual measurement with a caliper. However, such measurements will include inaccuracies which vary depending on the expertise of a particular user. The inaccuracies occur due to the manual placement of the caliper, variations in the manual force applied to the caliper, and the caliper blades cutting into the soft material of the bottle finish, such as when the bottle is made of a blown thermoplastic. If the calipers are tilted just a slight amount, the reading will fluctuate. Therefore, the measurements are very difficult to repeat.

As an alternative to manual measurement with a caliper, container finishes may also be measured by an optical comparator. The optical comparator takes an enlarged shadow-graph of the bottle finish to provide a highly accurate measurement of the finish diameter. However, optical comparators are quite expensive and are generally not available at the location where the bottles are made. Therefore, when using an optical comparator, bottles often must be shipped to a laboratory for measurement, providing a very delayed determination of dimensional tolerances. As a result, a large number of reject bottles may be made before the error is corrected by adjustments to the blow molding and/or trimming processes.

In view of the above drawbacks of the known methods for measuring S-dimension of a container finish, it would be desirable to provide a measuring device for accurately measuring the S-dimension of a container finish rapidly and with minimal user error.

SUMMARY OF THE INVENTION

In one aspect of the present invention, a measuring device for measuring the thread start distance of a thread formed on an outer surface of a first container finish includes a base comprising a first surface for receiving a rim of the first container finish, a support member movably attached to the base and adjacent the first surface such that a side surface of the support member is in contact with the first container finish, a gauge attached to the base, and a gauge actuator operatively associated with the gauge. The gauge actuator measures a distance between the rim of the first container finish and a thread start point of the thread of the container finish as the gauge actuator moves along an upper base line of the thread. Specifically, the distance between the rim of the first container finish and a thread start point is the thread start distance of the first container finish. The measuring device further includes a counterweight attached to the base to balance the measuring device on the first container finish.

In another aspect of the present invention, a process for measuring the thread start distance of a thread formed on an outer surface of a container finish includes the steps of positioning a first surface of a measuring device on an upper end of the container finish, moving a support member of the measuring device in contact with a side wall of the container finish, contacting a gauge actuator with an upper base line of the thread wherein the gauge actuator is operatively connected to a gauge having a display; and moving the gauge actuator along the upper base line of the thread so as to measure a vertical distance between a thread start point and the rim of the container finish.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following drawings, description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a fluid container having a finish portion;

FIG. 2A is a detailed schematic view of the finish portion shown in FIG. 1;

FIG. 2B is a top view of the finish portion shown in FIG. 2A;

FIG. 3A is a side view of the gauge system of the present invention that is mounted on a bottle finish for measuring the S-distance;

FIG. 3B is a detailed schematic view of the gauge actuator of the present invention;

FIG. 3C is a cross-sectional view of the gauge system shown in FIG. 3A;

FIG. 4 is a bottom view of the gauge system of the present invention shown in FIG. 3A; and

FIG. 5 is a perspective view of the gauge system of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made to the drawings wherein like numerals refer to like parts throughout. FIG. 1 illustrates an exemplary plastic container **100**, such as a bottle, to hold fluids such as detergent or bleach, or the like. The bottle may be manufactured by combining a first half **102** and a second half **104** through a molding part line **106** using well-known

processes in the art of container manufacturing. In the preferred embodiment, the bottle may be made of high-density polyethylene. The bottle 100 may comprise a top portion 108 with a bottom portion 110, and a body 112 of the bottle 100 is configured to retain fluids. A finish portion 114 is formed as an opening shaped as a neck or a short tube where the fluids are filled into or dispensed out of the bottle 100.

As shown in FIG. 2A, the finish portion 114 of the bottle 100 may be integrally connected to the body 112 through a shoulder portion 116 or shelf at a lower end 118 of the finish 114. An outer circumferential side wall 120 extends between the lower end 118 and an upper end 122 of the finish 114. On the outer circumferential side wall 120, the bottle finish 114 may have threads 124 for retaining a cap (not shown). In this embodiment, the threads 124 are defined by an upper surface 126 and a lower surface 128. The threads 124 project outwardly and extend along a spiral path around the finish 114. Further, the threads 124 extend generally, but not necessarily, between the upper and lower end 118 and 122 of the finish 114. The upper surface 126 of the threads 124 may adjoin the side wall 120 under an obtuse angle and along an upper base line 130. Similarly, the lower surface 128 may adjoin the side wall 120 along a lower base line 132. The upper base line 130 terminates at a thread start point 134 which forms the uppermost end of the thread 124 as in the manner shown in FIG. 2A. In this embodiment, the thread start point 134 is the first reference feature of an S-dimension 135.

As illustrated in FIG. 2B, in a top view of the bottle 100, the finish 114 may comprise an upper surface 136 or rim and inner circumferential side wall 138 defining a finish opening 140. In this embodiment, the upper surface 136 forms a second reference feature of the S-dimension 135. Accordingly, in this embodiment the S-dimension is the vertical distance between the thread start point 134 and the upper surface 136 of the finish 114. As previously mentioned, for containers which will hold fluids, including consumer products such as detergents and bleaches, it is important that the S-dimension of the container be within predetermined dimensional tolerances so that a cap will be retained properly on the finish and leaks will be prevented. Therefore, the S-dimension of the bottles must be routinely measured to determine whether the distance 135 between the upper surface 136 and the thread start point 134 is in predetermined manufacturing limits. A gauge system 200 of the present invention provides an effective tool to facilitate this measurement process.

FIGS. 3A and 3B show the gauge system 200 of the present invention which is placed on the finish portion 114 of the bottle 100 during the measurement process. The gauge system 200 of the present invention may comprise a base 202, a gauge 204, and a counterweight 206. The counterweight 206 comprises a cylindrical weight member that allows the system 200 to be balanced on the finish portion 114. The base 202 comprises a first side 208, a second side 210, a top surface 212 and a bottom surface 214. The counterweight 206 is attached to and extends from the second side 210 on which the gauge 204 is positioned. In this embodiment, the second side 210 of the base 202 is comprised of an L-bracket having a first arm member 216 perpendicularly attached to a second arm member 218. The L-bracket 210 is secured to the upper surface 212 of the base 202 through the second arm member 218 such that an upper surface 220 of the first arm member 216 is substantially parallel to the upper surface 212 of the base 202.

The gauge system 200 of the present invention can conveniently be custom manufactured for measuring the S-dimensions of various bottle sizes with differing finish opening diameters. In this embodiment, the gauge system 200 is adapted to operate on bottles having 33 and 38 millimeter finish diameters (FIG. 5). The gauge system may weight about 900 grams. Exemplary dimensions may be 7" length and 2.75" width. The base 202 may have a 1" height, and the overall height of the gauge (including top of gauge 204) may be 6". All machined pieces made from anodized aluminum except support member 242 made from delrin plastic, and the thumb screw is made of brass.

Referring to FIGS. 3A and 3B, during the measuring process, a first region 222 of the bottom surface 214 is placed on the finish surface 136 of the finish 114. A gauge actuator 224 of the gauge 204 is then extended to contact the upper base line 130 of the threads 124, and next the gauge system 200 is rotated towards the thread start point 134 to record the S-dimension. As the gauge system 200 is rotated, the gauge 204 records the distance between the upper base line 130 and the finish surface 136 based on the vertical displacement of the gauge actuator 224.

As illustrated in FIG. 3A, the gauge 204 is placed on the upper surface 220 of the first arm member 216 and comprises a front side 226 having a digital display 228, and control buttons 230 and 232 to control the gauge 204. The control buttons 230 and 232 may serve to perform a variety of functions to control the gauge 204, such as turning on and turning off the gauge 204, setting the zero readout, as well as changing the measurement mode between different units, for example between millimeters and inches. The gauge 204 may have a memory to hold the height measurements as it is rotated. However, measurements may be read off the digital display 228 by a user as well. The gauge 204 may be available from the Fred V Fowler Co, Newton, Mass. and sold under the brand name Ultra Digit Mark V.

As shown in FIG. 2B in detail and in FIG. 3B in cross-section, the gauge actuator 224 may comprise a gauge rod 236 extending through a hole 238 formed in the body of the first arm member 216 of the L-bracket 210, and a contact member 240, preferably a roller member, having a roller surface 242 to engage or contact the upper base line 130 of the bottle 100, as in the manner shown in FIGS. 3A–3C. The roller member 240 is movably attached to a first end of the gauge rod 236 using any one of the well known attachment methods in the art. The rotation axis of the roller member 240 is preferably perpendicular to the gauge rod 236. The second end of the gauge rod 236 has a tip 244 for manually controlling the vertical position of the gauge rod 236. As an example, the roller may be sized to have diameter of approximately ⅜" and a width of 5/32". The rod 236 may have a diameter of 3/32". The rod and the roller may be made of hardened and ground stainless steel.

Referring now to FIGS. 3A, 3B, and 3C, the first side 208 of the base 202 comprises an inner cavity 246 to movably retain a support member 248 on a cavity floor 250. The cavity floor 250 is a lateral extension of the bottom surface 214 and is in the plane of the bottom surface 214. During the calibration of the gauge system 200, the support member 248 is contacted with the threads 124 on the finish 114 thereby confining the finish 114 between the roller member 240 and the support member 248. This, in turn, prevents lateral movement of the gauge system 200 but allows rotational movement of the gauge system 200 during the measurements. As will be described in detail below, the support member 248 may be moved into a first position to permit the gauge system 200 to operate on a 38 millimeter finish or it may be moved into a second position to permit the gauge system 200 to operate on a 33 millimeter finish.

As it is moved in the cavity 246 and on the cavity floor 250, the support member 248 moves along a button 252 or a thumb nut which is placed on the top surface 212 of the base 202. The thumb nut 252 holds the support member 248 at the predetermined positions by tightening the thumb nut 252. The thumb nut 252 is connected to the support member 248 by a pin 254. The pin 254 is placed through a second hole 256 formed through the body of the base 204. The second hole 256 may be a rectangular hole allowing the button 252 to switch between the two predetermined positions. As will be described below, the support member 248 can be moved between the predetermined positions by rotating an adjustment screw 258 and hence moving the support member 248 between these predetermined positions. As mentioned, once the position is selected, the thumb nut 252 may be temporarily locked at that position by tightening the thumb nut 252.

As shown in FIG. 4 in a bottom view, the base 202 is surrounded by a rectangular-U shaped side wall 260 or lip projecting perpendicularly from the bottom surface 214 and extending along an outer wall 262 of the first side 208 of the base 202. The support member 248 is generally rectangular in shape and in engagement with the correspondingly shaped side wall 260. Depending on the diameter of the finish being tested, the support member 248 may be laterally moved in the cavity 246 in a first direction 264 and in a second direction 266 by moving the adjustment screw 258 (FIGS. 3A, 3C and 4). The adjustment screw 258 may comprise a threaded shaft 268 and a knob section 272. The threaded shaft 268 is placed through a hole 270 formed in a rear wall portion 274 of the side wall 260 and engages with a threaded hole 276 formed in a rear end 278 of the support member 248. Depending on the direction of the rotation, the support member 248 moves in the first direction 264 and the second direction 266. When the support member 248 moves in the first direction 264 and into the first position as shown with dashed lines, it contacts the rear wall portion 274 of the side wall. The thread pitch on the threaded shaft is finer than most adjustment screws, which makes the positioning of the support member 248 more precise.

A front end 280 of the support member 248 comprises a V-shaped recess 282 having side walls 284 to contact the finish 114 when the first area 222 of the gauge 200 is placed on top of the finish 114. In this respect, when the larger diameter finish is measured (i.e., the finish diameter of 38 millimeters), the support member 248 is moved in the first direction 264 to provide sufficient space on the first region 222. Accordingly, when the smaller diameter finish is measured (i.e., finish diameter of 33 millimeters), the support member 248 is moved in the second direction 266 to provide enough space on the first region 222 for the finish. In addition, through the side walls 284 the support member establishes two-point contact with the finish which also improves stability of the gauge system 200.

The calibration and measurement of the S-dimension with the gauge system 200 may be exemplified with reference to FIG. 5. As shown, a user may grasp the entire gauge system 200 and place it on the bottle finish 114 as in the manner described above. Then, the calibration of the gauge 204 is initiated by turning it on by the on/off button 230. Next, the gauge 204 is placed on a substantially flat reference surface (not shown) and the roller surface 242 is contacted with the reference surface. The gauge 204 is zeroed using the zeroing button 230 while holding the roller 240 against the flat reference surface. After the calibration step, the measurement process is initiated. During the measurements, the base 202 can be gripped between the thumb and the middle finger while the ring finger is used to rotate the knob 270 permitting one handed operation. Referring back to FIGS. 2A and 2B, accordingly, the knob 270 of the adjustment screw 258 is rotated and the support member is positioned for the desired finish diameter, in this example, 33 millimeters. The gauge system 200 is then placed on top of the finish 114 as in the manner described above and aligned such that the roller 240 rests at the edge of the upper surface 236 of the finish 114. Then, the knob 270 is slowly rotated until the roller 240 slides on the side wall down to the upper base line 130. In order to obtain accurate S-distance measurements, it is important that the roller be placed on the upper base line 130. The finer thread pitch of the adjustment screw 258 advantageously facilitates this adjustment. At this point, the gauge system 200 is rotated so that the roller 140 rolls up to the thread start point 134. The lowest reading displayed on the digital display 228 is recorded as the S-dimension 135. Upon completing the measurements, the on/off button 230 is pressed and the gauge system 200 is turned off. The gauge system may have a measurement range of 0–1" with 0.00005" resolution, 0.0002" accuracy and 0.0001" repeatability.

It should be understood, of course, that the foregoing relates to preferred embodiments of the invention and that modifications may be made without departing from the spirit and scope of the invention as set forth in the following claims.

We claim:

1. A measuring device for measuring the thread start distance of a thread formed on an outer surface of a first container finish, comprising:

a base comprising a first surface for receiving a rim of the first container finish;

a support member movably attached to the base and adjacent the first surface, a side surface of the support member being in contact with the first container finish;

a gauge attached to the base; and

a gauge actuator operatively associated with the gauge, the gauge actuator measures a distance between the rim of the first container finish and a thread start point of the thread of the first container finish as the gauge actuator moves along an upper base line of the thread.

2. The measuring device of claim 1, further comprising a counterweight attached to the base, the counterweight balances the measuring device on the first container finish.

3. The measuring device of claim 1, wherein an actuator is connected to the support member for selectively moving the support member between a first position and a second position.

4. The measuring device of claim 3, wherein the actuator is an adjustment screw.

5. The measuring device of claim 3, wherein when the support member is in the first position a first surface of the base receives the first container finish having a first predetermined diameter.

6. The measuring device of claim 5, wherein when the support member is in the second position the first surface receives a second container finish having a second predetermined diameter.

7. The measuring device of claim 6, wherein the first predetermined diameter is larger than the second predetermined diameter.

8. The measuring device of claim 1, wherein the gauge actuator comprises a contact member and a rod.

9. The measuring device of claim 8, wherein a first end of the rod is operatively connected to the gauge.

10. The measuring device of claim 9, wherein the contact member is movably connected to a second end of the rod.

11. The measuring device of claim 10, wherein the contact member is a roller having a rotational axis perpendicular to the rod.

12. The measuring device of claim 11, wherein the contact member is a roller having cylindrical shape.

13. The process of claim 1, wherein the step of moving the support member of the measuring device in contact with a side wall of the container finish comprises contacting a recessed surface of the support member with the side wall of the container finish.

14. The process of claim 13, wherein the recessed surface contacts the side wall of the container finish at two points, thereby stabilizing the measuring device on the container finish.

15. The process of claim 1, wherein the support member is moved by rotating an adjustment screw.

16. A process for measuring the thread start distance of a thread formed on an outer surface of a container finish, comprising the steps of:

positioning a first surface of a measuring device on an upper end of the container finish;

moving a support member of the measuring device in contact with a side wall of the container finish;

contacting a gauge actuator with an upper base line of the thread wherein the gauge actuator is operatively connected to a gauge having a display; and

moving the gauge actuator along the upper base line of the thread so as to measure a vertical distance between a thread start point and a rim of the container finish.

17. The process of claim 16, wherein the step of contacting the gauge actuator comprises contacting a roller member with the upper base line of the thread.

18. The process of claim 1, wherein the step of moving the gauge actuator comprises a step of rotating the measuring device until the roller member reaches the thread start point.

19. The process of claim 18, wherein the thread start distance is the shortest distance displayed by the display.

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